the earth plate E, as shown in view (a). In the arrangement shown in view (b) the supply feeder b and the return feeder e are connected, respectively, to the primary and secondary windings of the current transformer f. Then, since the current in the two windings must be practically equal, all the return current must pass through the return feeder e. Thus, although there may be, and probably will be, a little leakage into and out of the

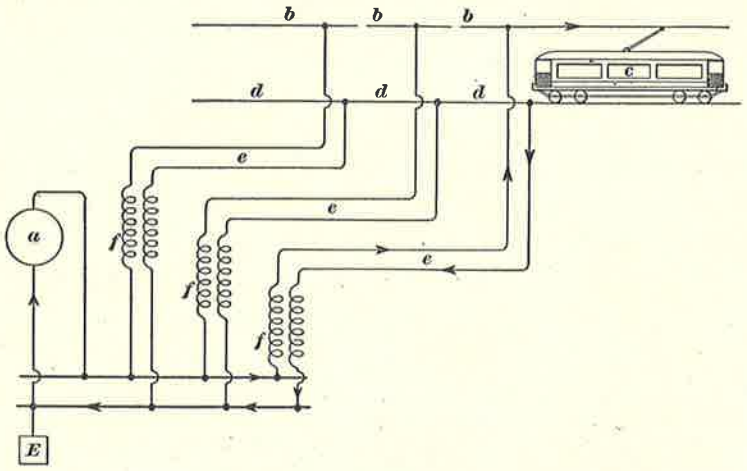

FIG. 62

uninsulated return, as indicated by the arrowheads, the greater part of the return current will pass along the rails, and there will be very little current in the earth. Where separate feeders are used, a sucking transformer should be connected in each, as shown in Fig. 62, which is lettered similarly to Fig. 61. There are several other methods of connecting the transformers to the feeders and return circuit, but the principle of action is the same in all.

ELECTRIC SIGNALLING ON RAILWAYS

SYSTEMS OF SIGNALLING

FORMS OF RAILWAY SIGNALS

EARLY TYPES

1. Necessity for Signals.—The introduction of the modern block-signal systems on large railways has greatly increased the efficiency and safety of train movements. By dividing the tracks into sections, called **blocks**, and installing certain safety devices, one train cannot approach another too closely without passing a warning signal, called a **block signal.**

On some of the early railways, where there was only one train running between two points, no signalling was required. With the development of the railways and the corresponding increase of trains and train movements on the same track, it became necessary to arrange for meeting points of the trains; to install sidings for the passing of the trains; to protect trains moving in the same direction by signals, in case the trains should come nearer to each other than a certain predetermined space; and to protect trains moving in opposite directions by blocking.

2. Ball-and-Mast Signal.—In Great Britain, long before the telegraph was invented, signalling between stations was effected by means of a large ball that was raised or lowered on a high mast. One of these signalling devices was situated at each station and was operated by an attendant, whose duty was to

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watch the signals at adjacent stations. Thus, for example, when a train left station No. 1, the ball would be raised to the top of the mast. When the train left station No. 2, the ball at that place would be raised to the highest position and the ball of station No. 1 would be lowered to half mast. When the train left station No. 3, the ball at that place would be raised to the highest position, the ball at station No. 2 would be lowered to half mast, and the ball at station No. 1 would be lowered to the ground. In this manner, the attendants at the stations were informed regarding the location of the trains. This system, however, could only be worked with stations very close together, and then only in day time and when the weather was clear.

SEMAPHORE SIGNALS

3. Home Signals.—In many modern signalling systems the driver of a train is informed of the condition of the block the train is approaching by means of movable signal arms, called **semaphores.** The arms are pivoted on posts and are arranged to move coloured lenses in front of a lantern, so that it is possible to tell the position of the semaphore at night by the colour of the light. A common form of semaphore is shown in Fig. 1. In view (*a*) the signal arm *a* is horizontal and the red lens *b* is brought in front of the lantern, so that at night a red light is displayed. In the position shown, the signal indicates that the block is occupied and the driver of the approaching train is to stop. In view (*b*) the arm *a* is at an angle of nearly 60° below the horizontal and the green or white lens *c* is brought in front of the lantern, so that at night a green or white light is displayed. In this position the signal indicates that the block is clear and the approaching

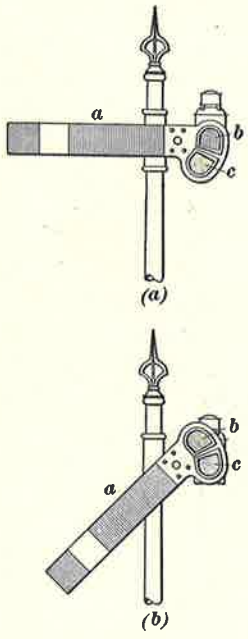

FIG. 1

train may proceed. A signal which shows the condition of the block immediately ahead is called a **home signal.**

4. Distant Signals.—It is often desirable to indicate at the entrance to one block the condition of the next succeeding block. In order to do this, special signals, called **distant signals,** are installed, and are arranged to indicate the position of the home signal one block in advance. The arm *a*, Fig. 2, of the distant signal is often provided with a **V** notch at the end, so that it may be distinguished from the home signal. If the distant signal is in the position shown in view (*a*), it indicates that the home signal, one block in advance, is at the danger position and the driver of the train must approach it with caution and be prepared to stop. If the signal is in the position shown in view (*b*), it indicates that the home signal one block in advance is at the proceed position. In this case the driver of the train knows that the two blocks ahead are clear and the train may proceed at full speed. Coloured lights are used to give the indications at night, as in the home signals.

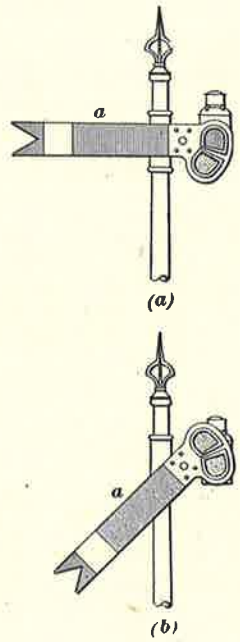

FIG. 2

5. Arrangement of Home and Distant Signals.—The home signal *a* of one block is often mounted on the same post as the distant signal *b* for the next block in advance, as shown in Fig. 3. The home signal is placed above the distant signal and indicates whether or not a train is in the block immediately ahead. If the semaphores are in the positions shown in view (*a*), the driver of the approaching train must stop before entering the block. If the semaphores are in the position shown in view (*b*), the driver is informed that the first block is clear, but the next home signal is at danger, and he must be prepared to stop the train at that signal if it still indicates danger when the train has reached the far end of the first block. When the semaphores are

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in the position shown in view (*c*), the two blocks ahead are clear and the train may proceed at full speed.

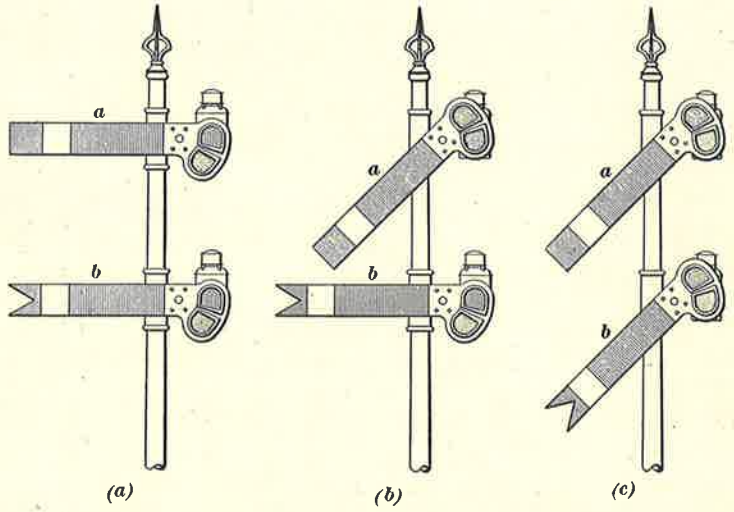

FIG. 3

6. Banner-Type Signal.—A type of signal sometimes used on lines at points where the running speed is not high is shown in Fig. 4. This signal is known as the **banner type**, and gives the same indication by day and night. It consists of a red banner arm *a* enclosed in a weatherproof case, the front of which is plain glass, and the back opalescent glass. The arm is pivoted at the centre, and in the danger position is horizontal, as shown. The clear position is indicated by the dotted lines. In day time, the light shining through the opalescent glass at the back shows up the arm very clearly, and at night a lamp is placed behind the signal, so that the same indication is given as during the day. The signal is operated electrically by the action of an electromagnet.

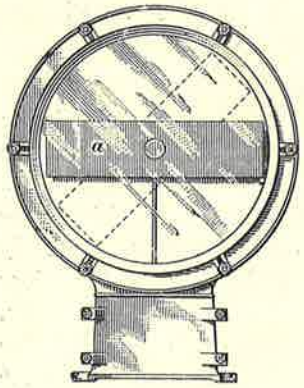

FIG. 4

TELEGRAPHIC BLOCK SYSTEMS

THREE-WIRE BLOCK TELEGRAPH INSTRUMENTS

7. Types of Block Telegraph Instruments.—Railway signalling which is accomplished by means of telegraphic block instruments, which the signalmen use to communicate with one another the conditions of blocks over which they have control, is known as the **telegraphic block system.** With this method of signalling the manipulation of the signals themselves is left to the intelligence of the signalmen, and the telegraphic block instruments are not interlocked in any way with the signals. This system of signalling is still in use on many railways. The block telegraph instruments in use may be broadly divided into two types: (*a*) Instruments in which the indicators are held in position by a constant current in the line, and which indicate *line clear* or *train on line*, according to the direction of flow of the current, and give the indication *line blocked* when current is switched off. This type usually requires three line wires. (*b*) Instruments which are made to indicate *line clear* and *train on line* by momentary currents in opposite directions, the indicators being held in position by the residual magnetism in the electromagnets after the current ceases to flow. These instruments usually require only one line wire.

8. Construction of Simple Three-Wire Instrument.—For three-wire working, separate wires are provided for the up and down lines and for the bell. In Fig. 5 is shown the appearance of the simplest type of instrument for three-wire working. The upper part *a* consists of a simple galvanometer, the needle of which can be made to deflect in either direction, according to the way current is passed through it. When deflected to the right, the needle indicates *line clear;* when deflected to the left, it indicates *train on line;* and when hanging vertical, *line blocked.* The lower part *b* of the instrument contains a simple commutator attached to the handle *c*, by means of which the direction of the current sent out by the instrument from the battery to the line

can be varied at will. When the handle *c* is in the central position, no current is sent out to the line. When moved to the left, current is sent to the line in such a direction that *line clear* is indicated on the distant instrument and on the dial above the handle. Similarly, if the handle is moved to the right, *train on line* is indicated. The positions of the handle when moved to one side or the other are shown dotted. When the handle has been moved to either position, it is held there by passing the peg *d* through a hole in the hollow spindle *e*, on which the handle is mounted; the peg passes between the pins *f*.

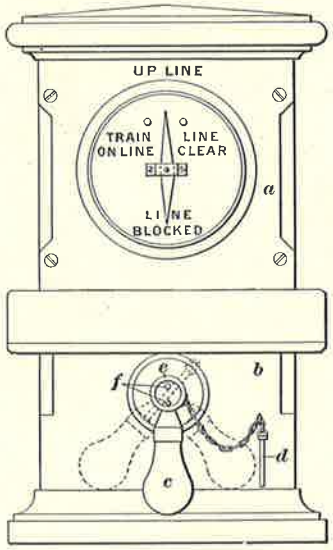

FIG. 5

9. Operation of Three-Wire Instrument. — Four single block telegraph instruments are required in a signal station or box, one for the up line and one for the down line, connected to the next signal box on the right, and a similar pair connected to the next signal box on the left. The bells are separately wired up, and are not included in the instrument. Suppose that a train is to be sent from A to B. The signalman at A gives a definite pre-arranged number of strokes on the bell to signalman at B, who, if the block is clear, so that the train will meet no obstacles, turns the handle of the commutator of the telegraph instrument to the left, and pegs it there, thus causing the needle of the instrument at B and the needle of the corresponding instrument at A to indicate *line clear*. When the train leaves A, the signalman there signals the fact by means of the bell, and the signalman at B turns the commutator of the instrument to the right, and fixes it there, thus indicating *train on line* on both instruments. On the arrival of the train at B, the signalman there turns the handle so that both instruments indicate *line blocked*.

10. Combined Instruments.—For convenience in working, the instruments for the up and down lines and the bell are often combined into a single instrument. The arrangement of such an instrument is shown in Fig. 6. The dials *a* and *b* for the up and down lines, respectively, are placed in the upper part of the instrument; the dial *c* indicates the last signal given to the next box. The commutator is actuated by turning the disc *d* in one direction or the other, and the spindle of the plunger *e* for operating the switch of the signal bell circuit passes through the centre of the disc. Two instruments of this type are required in each signal box, one being connected to each adjacent box.

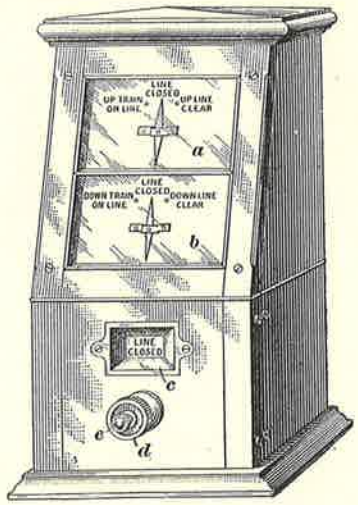

FIG. 6

ONE-WIRE BLOCK INSTRUMENTS

11. Tyer One-Wire Block Instrument.—The general appearance of a Tyer one-wire block instrument for giving three distinct indications is shown in Fig. 7. There are two pointers *a* and *b*, which refer to the up line and the down line, respectively. At the bottom of the instrument is a handle *c* for turning the commutator. A disc inside the instrument brings the words *line blocked*, *train on line*, or *line clear* into view in the window *d* as the commutator is turned to one of its three positions. The plunger *e* for ringing the bells projects from the centre of the commutator handle. The small plunger *f* operates a stop-lever, or detent, to stop the commutator in the desired position. The ringer is mounted in a separate case *g*, which also contains a relay. The instruments at adjacent signal boxes are connected and lettered so that the pointers for the down line operate in unison and also the pointers for the up line act together.

12. Arrangement of Fields and Armature.—In the Tyer one-wire block instrument there are two field poles a, a_1, Fig. 8 (a), and two permanently magnetized exciting poles b, b_1 for each of the armatures c and c_1. The armature is a hollow cylinder of iron, split longitudinally and mounted on a brass boss. When the armature is in the position shown, the needle attached to the armature is inclined to the left, indicating *line blocked* on the face of the instrument. If poles a and b are of north polarity, and a_1 and b_1 of south polarity, the armature c will turn in a clockwise direction, so that the lines of force passing from a to b_1 and from b to a_1 will have a path of low reluctance through the iron. If the polarity of the main field poles a, a_1 is reversed, while the polarity of the exciting field poles remains unchanged, the armature c will turn in a counter-clockwise direction, so that the two iron segments will carry the lines of force from b to a and from a_1 to b_1. The motion of the armature in a clockwise direction may be limited by the stop d, which is controlled by the unlocking magnet e.

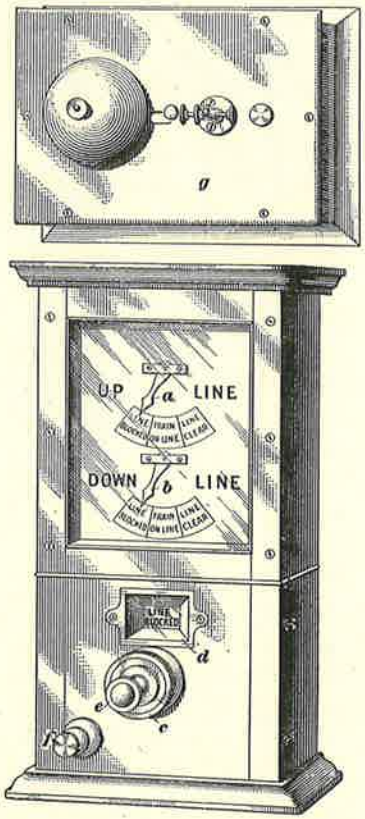

FIG. 7

13. Arrangement of Commutator.—The commutator used in the Tyer block instrument is made up of three sectors f, g, and h, Fig. 8 (a), insulated from the main contact-piece i. On the sector h a contact pin projects some distance beyond the face of the sector, so that when it is in the proper position, immediately over the earthing spring j, it will make contact with the spring if the plunger is depressed. The spring j makes contact with the commutator only for the one position. The three positions of the commutator for sending the signals *line clear*, *line blocked*, and *train on line*, respectively, are shown on the diagram.

14. Operation of Tyer Block Instrument.—If a train is to be sent from station A, Fig. 8 (a), to station B, Fig. 8 (b), the method of operating the block instruments is as follows: The signalman at station A will depress the plunger of the instrument at A, thus connecting the springs k, l, and m together, provided the commutator is in the position marked *line blocked*. The earthed spring j is also connected to spring n and thus to the negative pole of the battery o. Current will flow from the positive terminal of battery o to terminal *1*–winding of unlocking magnet p–spring m–commutator sector i–spring k–special terminal *2* of the battery o. The armature q of the unlocking magnet p is raised so that the armature c_1 can move its full distance in a clockwise direction. From the special terminal *2* of the battery o current also flows through springs k and l–line terminal *3* and line to terminal *3′* of the instrument at B–spring l'–contact *4′*–terminal *5′*–coils a', a'' of main field for armature c'–terminal *6′*–terminal *7′* of relay–relay windings r'–terminal *8′*–earth terminal *9′*–earth terminal *9* on instrument at A–spring j–commutator sector h–spring n–negative terminal of battery o. The armature of relay r' of instrument at B will be drawn only to the spring stop s' and current will flow from the positive terminal of the battery o'–terminal *1′*–exciting coils b', b'' for armatures c' and c''–terminal *10′*–terminal *11′*–armature of relay r'–spring stop s'–unlocking coil e'–terminal *12′*–terminal *13′*–coils t' of ringer–terminal *14′*–commutator spring n'–negative terminal of battery o'. A signal is thus given on the ringer at station B and the pointers remain at the normal line-blocked position.

15. If the line is clear, so that the train from station A, Fig. 8 (a), can be accepted, the signalman at B, Fig. 8 (b), will turn the commutator of the instrument to *line clear* and depress the plunger. This action causes the lower pointer of the instrument

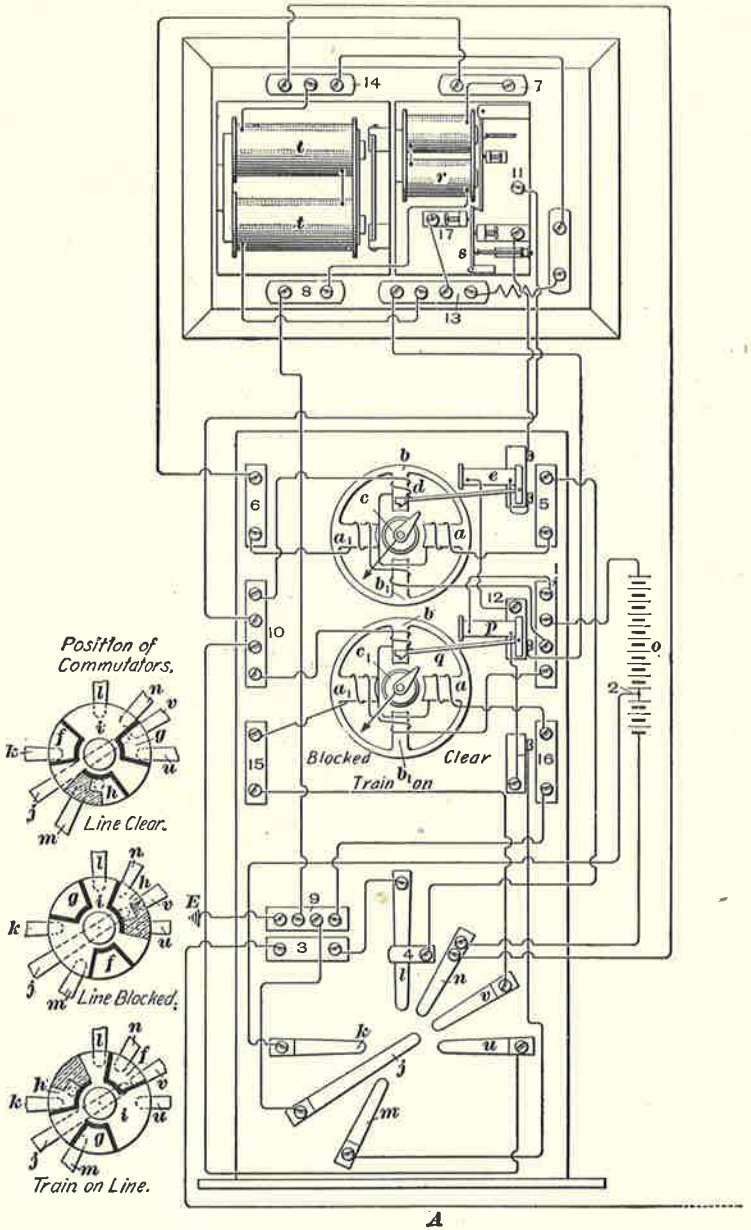
Position of Commutators.
Line Clear.
Line Blocked.
Train on Line.
Blocked
Clear
Train on
A

FIG. 8 (*a*)

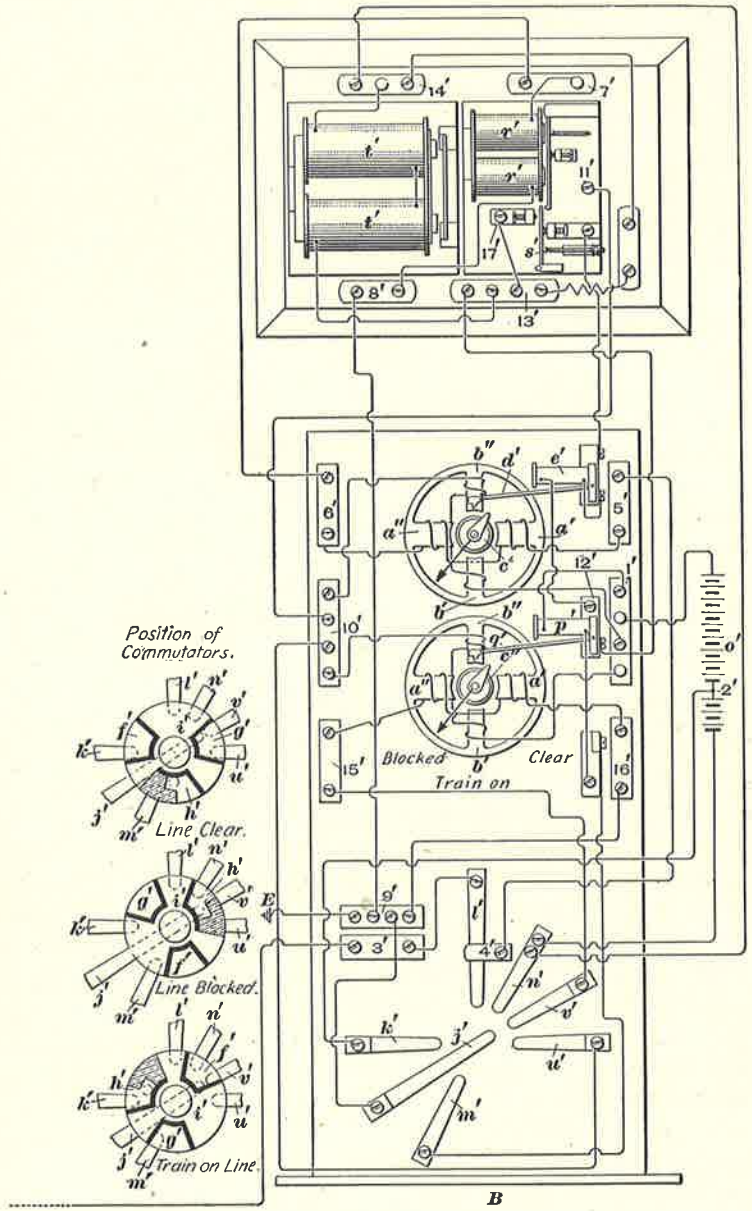
Position of Commutators.
Line Clear.
Line Blocked.
Train on Line.
Blocked
Clear
Train on
B

FIG. 8 (*b*)

at B and the upper pointer of the instrument at A to show *line clear*. Both these pointers refer to the up line, and therefore there is no chance of confusion. The path of the current is from the positive terminal of battery o' – terminal $1'$ – exciting fields b', b'' for armature c'' – terminal $10'$ – spring u' – commutator sector g' – spring v' – terminal $15'$ – fields a'', a' for armature c'' – terminal $16'$ – terminal $9'$ – earth E to instrument at A – terminal 9 – terminal 8 – coils of relay r – terminal 7 – terminal 6 – fields a_1, a for armature c – terminal 5 – contact 4 – spring l – terminal 3 – line to instrument at B – terminal $3'$ – spring l' – segment i' – spring n' – negative terminal of battery o'. The armature of relay r at station A will be drawn against the stop 17, and a local circuit will thus be formed from the positive terminal of battery o – terminal 1 – exciting fields for armatures c and c_1 – terminal 10 – terminal 11 – armature of relay r – stop 17 – terminal 13 – coils t of ringer – terminal 14 – spring n – negative terminal of battery o. Armatures c of instrument at A and c'' of instrument at B will turn, so that the pointers indicate *line clear*. The signalman at station A will then set the outdoor starting signal at clear, and by means of the bell indicate to the signalman at B that the train is entering the section.

16. The signalman at station B, Fig. 8 (b), will reply to the train entering section signal by turning the commutator of the instrument to train on line and pressing the plunger. This action connects the negative terminal of the battery o' through spring n' – commutator sector f' – spring v' – terminal $15'$ – main fields a'', a' for armature c'' – terminal $16'$ – terminal $9'$ – to the earth, and the positive terminal of battery o' through exciting coils b', b'' for armature c'' – terminal $10'$ – spring u' – sector i' – spring l' – terminal $3'$ – to the line. The reversing of the battery connections in this way causes the armatures c'' and c to turn in a clockwise direction as far as the stops q' and d will allow, and will cause the pointers to indicate train on line.

After the train has passed out of the section, the signalman at B will turn the commutator of the instrument to line blocked and depress the plunger. This action will restore the instruments to their normal condition.

LOCK-AND-BLOCK SYSTEMS

AUXILIARY APPARATUS FOR LOCK-AND-BLOCK SYSTEMS

17. Necessity for Interlocking.—The safe operation of a telegraphic block system depends on the signalmen implicitly obeying the indications of the block instruments, and using the utmost care in performing shunting and other operations. Accidents have frequently occurred through the failure of signalmen to work the signals in accordance with the indications given by the block instruments. In order to prevent mistakes of this kind, many interlocking systems have been developed, in which the signalman is compelled, by interlocking the outdoor signals with the block instruments, to work the signals in accordance with the indications of the block instruments. In the **lock-and-block system,** the signals and telegraphic instruments at both ends of a block are interlocked in such a way that it is impossible for a clear signal to be set, except by the simultaneous co-operation of the signalmen at both ends of the block. In this system, the signal is normally locked in the stop position, and communication between stations is maintained by telegraph, by telephone, or by code bells.

18. Use of Rail Contacts.—Rail contacts, or **treadles,** are used to complete the circuit of certain electromagnets, which lock the signals and prevent them from being lowered until the train has passed over the rail contacts, when the electromagnets unlock the signals. They are also used to put signals to danger after the passage of a train. It is essential that a rail contact shall be sure in action, and it must not be capable of being actuated by hand, or by being walked or jumped on, or by a moderate weight falling on it. In order to comply with these requirements, it is clear that the only satisfactory rail contact is one which is actuated by the deflection of the rail when a train passes over it.

19. Sykes Rail Contact.—There are numerous types of rail contacts in use, one of the best known being the Sykes rail contact, shown in Fig. 9, view (a) being a side view of the rail and treadle

attachments, view (*b*) a plan, and view (*c*) an end view. The angle-iron treadle *a* is carried by the cast-iron brackets *b* and *c*, which are firmly bolted to the rail *d*. Midway between the brackets *b* and *c* a third bracket *e* is attached to the rail; the end of the bracket bears on the short ends of two levers *f* and *g*, which are pivoted to the treadle *a* at the points *h* and *i*, respectively. The other ends of the levers *f* and *g* are situated immediately beneath the mercury cups *j* and *k*, which are pivoted between the treadle *a* and brackets *l* and *m* attached to the treadle. Each mercury cup is furnished with two contact wires, which are connected by the mercury when the mercury cups are tilted. The action of the device is as follows: When a train passes, the bracket *e* is depressed and forces down

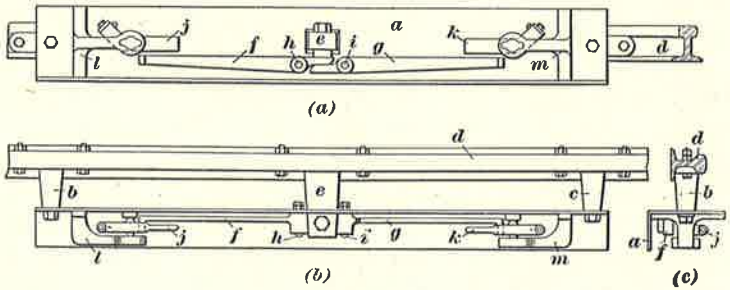

Fig. 9

the short arms of levers *f* and *g*, causing their long arms to rise and tilt up the mercury cups *j* and *k*, thus making contact between the contact wires dipping into the mercury cups. The two sets of contact wires are connected in parallel, thus reducing the risk of failure.

20. Siemens Rail Contact.—Another type of rail contact in which mercury is employed is the Siemens contact, shown in Fig. 10, view (*a*) being a side view of the complete apparatus, and view (*b*) an end section. The device is supported from the flange of the rail *a* by the small girders *b*, which are attached to the flange by bolted clips *c*. The main mercury container is situated immediately below the rail, and is divided into two portions by a thin flexible steel diaphragm *d*, the space under the diaphragm being filled with mercury. On the top of the

diaphragm is placed a cast-iron disc *e*, in contact with which is the cylindrical steel plunger *f*. This plunger passes through the cover *g* of the container and just touches the under side of the rail flange. Between the cover *g* and the under side of the rail flange, encircling the plunger *f*, is placed an india-rubber ring *h*, to prevent sand or dirt from interfering with the action of the plunger. When a train passes over the device, the downward movement of the rail *a* is transmitted by the plunger *f* and disc *e* to the diaphragm *d*, which also moves downwards, and forces

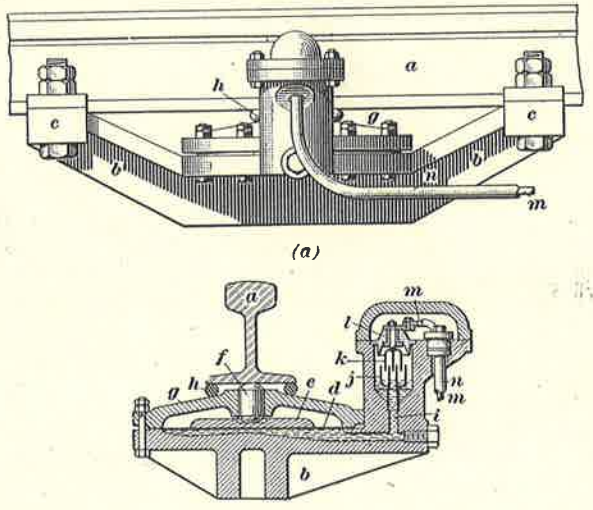

Fig. 10

some of the mercury beneath it up the pipe *i* and into the cup *j*, where it joins up the contacts of the fork *k*. The fork *k* is carried on a slate cap *l*, and is connected to a wire *m*, which passes out of the apparatus through the pipe *n*. The cup *j* is provided with openings which allow the mercury to run out when the pressure is removed from the rail.

21. Hollins Treadle.—A form of rail contact, known as the **Hollins treadle** and used on the Great Eastern Railway, is shown in Fig. 11, view (*a*) being a side elevation and view (*b*) an end elevation of the contacts. In this type of treadle the use of

mercury is avoided by the employment of a metal contact-piece making a rubbing contact with two springs. The lever *a* is pivoted at *b*, and is provided with a tail-piece *c*, which is let into a slot in the web of the rail *d*. Attached to the other end of the lever, but insulated from it by the insulation *e*, are two brackets *f*, *g*, which support a curved steel rod *h*. The bracket *i*, which carries the wedge *j*, is arranged to be a sliding fit on the curved rod *h*, so that if sufficient pressure is placed on the bracket *i* it will slide on the rod. When a train passes, the short arm of the lever *a* is depressed and the long arm rises, taking with it the bracket *i* and contact wedge *j*, thus causing the metallic portion *k* of the wedge to make contact with the springs *l*, *m*. Two steel stops *n* and *o* limit the movement of the bracket *i* to the required amount; should the movement of the lever be greater than is

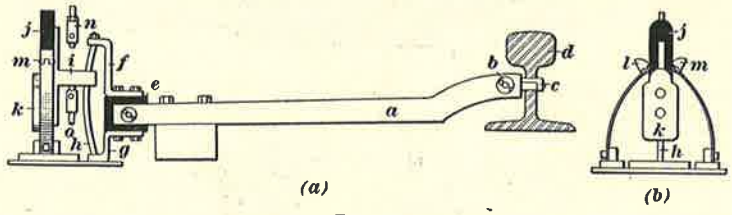

FIG. 11

required, the bracket *i* comes in contact with one of the stops and the rod *h* slides through the bracket *i*. The device is thus self-adjusting, and is very satisfactory, the number of failures in practice averaging less than 1 in 1,000,000 operations.

22. Fouling Bars.—On certain parts of a railway, as at terminal stations and sidings, a device known as a **fouling bar**, which is actuated by a train standing at the station, or in the siding, is required. In the case of a terminal station, this device must indicate that the particular line is occupied by a train, and so lock the signals that a signalman cannot admit another train on the same line. In the case of a siding, the device is used in conjunction with a rail contact, and prevents the signalman from admitting another train to the section until the first train is completely in the siding and clear of the main line.

23. The construction and action of a Sykes fouling bar are shown in Fig. 12, view (*a*) being an elevation and view (*b*) a plan. By the side of the rail *a* is placed an angle-iron bar *b* carried on the ends of levers *c* pivoted at *d*. The other ends of the levers *c*

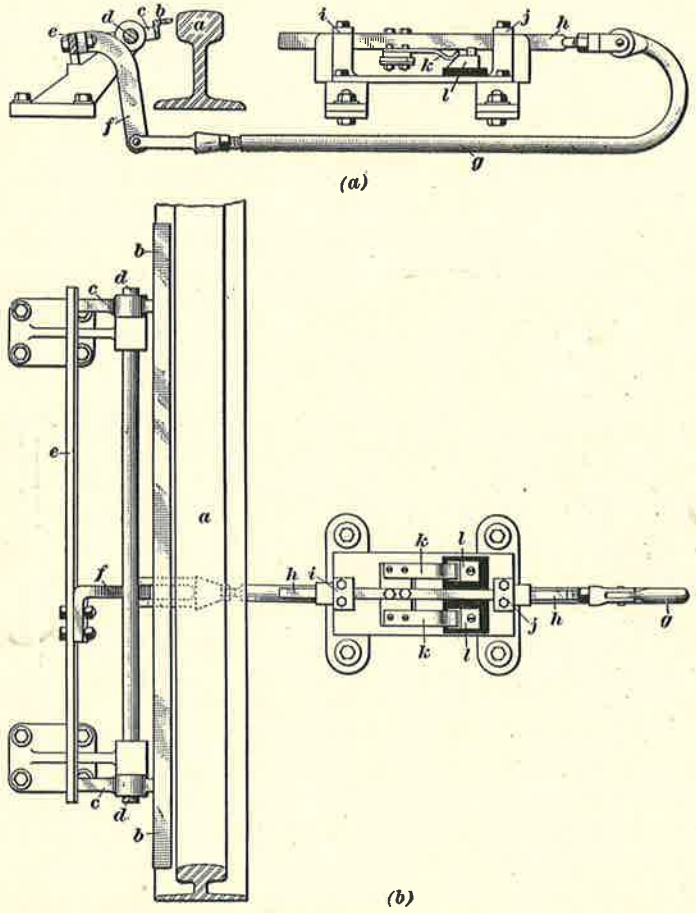

FIG. 12

are attached to the heavy bar *e*, which is connected by means of the arm *f* and the curved rod *g* to the bar *h*, which slides in the bearings *i* and *j*. To the under side of bar *h* are attached contact springs *k*, which normally make contact with the blocks *l*.

These blocks are mounted on insulating bases and form the terminals of the device. When a train is standing over the fouling bar *b* it is depressed by the flange of a wheel ; this raises the bar *e*, which, through the arm *f*, pulls on the rod *g* and causes the bar *h* to slide through the bearings *i*, *j*, thus breaking contact between the springs *k* and blocks *l*. The bar *b* must be made of greater length than the maximum distance between two axles on the train, in order to ensure that at least one wheel flange shall depress the bar.

24. Sykes Signal Reverser or Replacer.—It is desirable on a lock-and-block system that a train shall automatically place a signal that it passes to danger, independently of the signalman, as this ensures that the signal will always be at danger when the

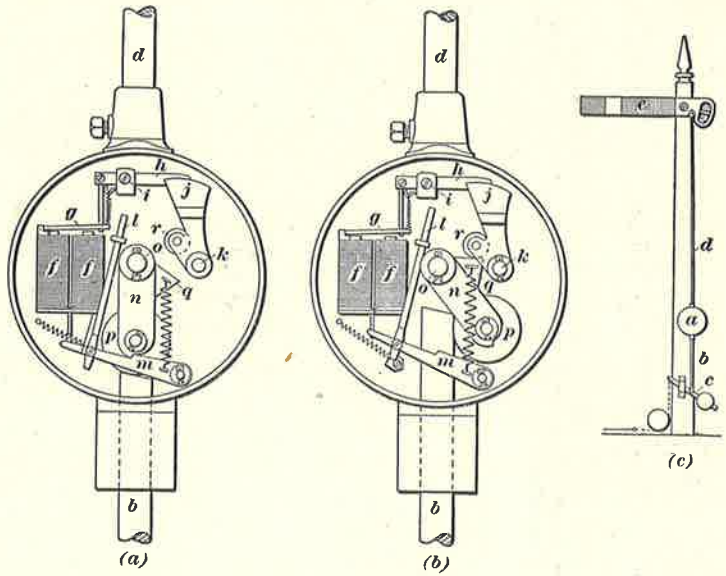

FIG. 13

block is occupied. A piece of apparatus for this purpose is called a **signal reverser,** or **signal replacer.** The details of construction of a Sykes signal reverser are shown in Fig. 13. It is placed as shown at *a* in view (*c*), and divides the vertical signal

rod into two parts, the lower of which, *b*, is joined to the balance-weight lever *c*, and the upper, *d*, to the signal arm *e*. The upper part *d* is fixed to the case of the reverser, and the lower *b* slides into the case, as shown in views (*a*) and (*b*), which illustrate in detail the mechanism of the reverser.

25. The mechanism of the Sykes signal replacer is shown in Fig. 13 (*a*) in the position it occupies when the signal is clear, or off, and the lever controlling the signal in the signal box is also at clear. When a train passes the signal, it operates a rail contact, which allows current to flow through the windings of the electro-magnets *f*, the poles of which attract the armature *g*, thus raising the end *h* of a small lever pivoted at *i*, and allowing the hammer *j*, which is pivoted at *k*, to fall. At the end of its stroke, the hammer *j* strikes the upper end of rod *l*, depressing it and also the lever *m* to which it is attached. This releases the arm *n*, which is normally held vertical by a catch on lever *m*.

26. The arm *n*, Fig. 13 (*a*), is pivoted to the case of the reverser at *o*, and carries on its free end the steel roller *p*. Owing to the tendency of the signal arm to return to the danger position, when the signal is at clear, there is a constant pressure of the roller *p* on the top of the rod *b*, which is bevelled. The roller *p* and arm *n* thus continually tend to move to the right, but are prevented from doing so by the lever *m*. When the arm *n* is released in the manner just described, the roller and arm move to the right, the whole case of the reverser slides down over the rod *b*, and the signal goes to the danger position. As the rod *n* moves to the right, the projection *q* engages with the steel roller *r*, and raises the hammer *j* to the vertical position, where it is held by a catch on the lever *h*. The mechanism is then in the position shown in view (*b*). When the signalman puts the signal lever to the danger position, the rod *b* is withdrawn from the case of the reverser by the balance-weight lever *c*, view (*c*), and the arm *n* and roller *p* then return to the position shown in view (*a*). This device thus automatically puts the signal to danger after a train passes into the block and the signalman cannot place the signal at clear until he has first put the signal lever to the danger position.

27. Tyer Signal Replacer.—The working parts of a Tyer signal replacer are protected by a box *a*, Fig. 14, which is fastened to the lower section *b* of the vertical signal rod by the pivot *c*. The upper part *d* of the signal rod is free to slide into and out of the replacer box *a*. The mechanism is shown in the position it would have if the signal were at clear. When a train passes into the block it actuates a track contact and thus causes current to flow through the coils *e* of the electromagnet. The magnet will attract the armature *f*, which will turn drum *g* so that the tip of the hook-shaped lever *h* can pass through a slot in the drum. The lever tends to move to the right about pivot *c*, because of the pressure of the sloping end of rod *d* on the roller *i* of the lever *h*. The rod *d* will slide past the roller and the signal will go to danger position. When the signalman places the signal lever at danger, the replacer box *a* slides down rod *d* and the weight of the hook lever *h* brings it to its original position, where it is held by the drum *g*.

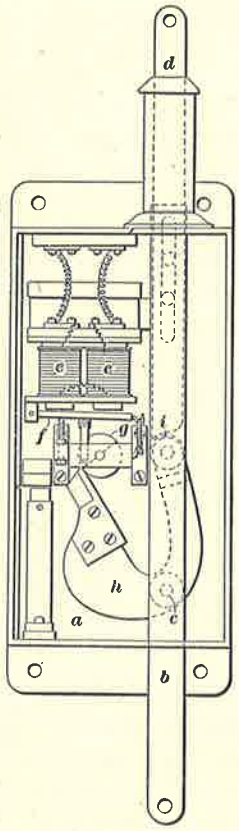

FIG. 14

28. Light Indicator.—It is customary on British railways, especially when the signalman cannot see the signal lights, to provide light indicators in the signal cabins. These instruments show whether or not the signal lamp is lighted, and, in the event of the light going out or burning low, ring a bell to notify the signalman of the fact. The way in which this indication is effected is shown in Fig. 15. The signal lamp *a* contains two pillars, which support a copper rod *b* immediately above the flame *c* of the lamp. This rod *b* is so arranged that its expansion when heated by the lamp flame causes it to complete the circuit between the two supporting pillars in the lamp.

Current then flows from the battery *d* through the rod *b* and line wire *e* to the indicator *f*; it then passes through the coils of the relay *g*, and returns to the battery *d* by way of the earth plates *E*. The completion of the circuit causes the needle of indicator *f* to point to *in* and the relay *g* to attract its armature *h*. Should the light in the lamp go out or get too low, the circuit through the rod *b* would be broken, the indicator *f* would point

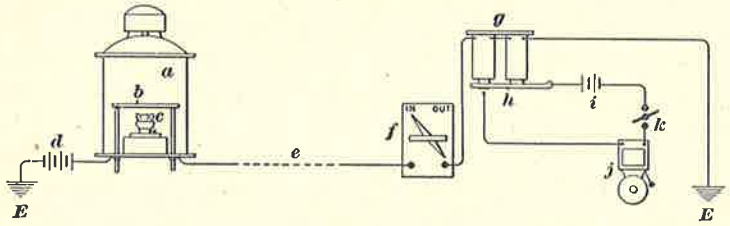

FIG. 15

to *out*, and the relay *g* would drop its armature *h*, thus completing a local circuit from the battery *i* through bell *j* and switch *k*. The bell continues to ring until the signalman turns it off by means of the switch *k*. Where several signals are situated close together, their light contacts can be connected in series to a common indicator, on which the failure of any one of them will be shown. This often effects a considerable saving in instruments and wiring.

29. Signal Repeater. The position of signal arms which are not readily visible to the signalman should be repeated in the signal box. One method of doing this is shown in Fig. 16. The signal arm *a* is provided with a tubular mercury commutator *b*, the main metal body of which is earthed. Contacts *c*, *d* project

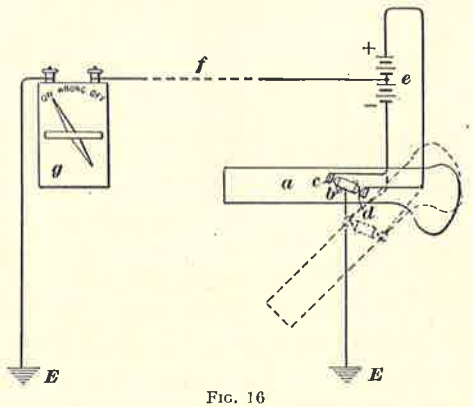

FIG. 16

into the tube at each end, but are insulated from the main body of the commutator. These contacts are connected to the terminals of the battery *e*, and a line wire *f* from the middle point of the battery runs to one terminal of the indicator *g*, the other terminal of which is earthed. When the signal arm is on, that is, in the danger position, current flows from the positive pole of the battery to contact *d*, and by way of the mercury in the tube to the main body of the commutator and to earth. It then passes through the indicator *g*, causing it to indicate *on*, and returns to the middle point of the battery on the line wire *f*. The upper half only of the battery is used to give this indication. When the signal arm is off, that is, in the clear position, the mercury in the commutator connects the negative pole of the battery to earth. The direction of the current through the indicator *g* is thus reversed, and the indication *off* is given, the lower half only of the battery being used. If the signal arm should fail to go fully to the on- or off-position, the mercury in the commutator does not make connection with either contact *c* or *d*, and the indicator is not energized in either direction ; it then indicates *wrong*.

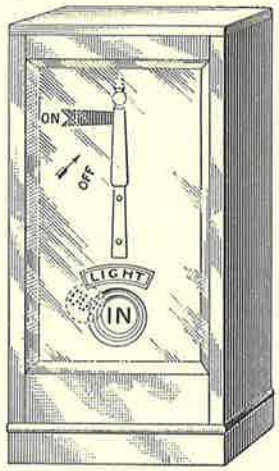

Fig. 17

30. The light indicator and signal repeater for one signal are often placed in one case in the signal box, thus avoiding confusion. The needle of the signal repeater is often replaced by a miniature semaphore arm, which can be coloured and either plain or slotted at the end, thus indicating which signal it is repeating. The appearance of such an instrument is shown in Fig. 17. The condition of the light is indicated by the appearance of discs, lettered *in* and *out*, opposite the circular aperture in the lower part of the instrument. If anything is wrong with the signal, the semaphore arm stops opposite the arrow, but otherwise indicates *on* or *off* in accordance with the position of the signal.

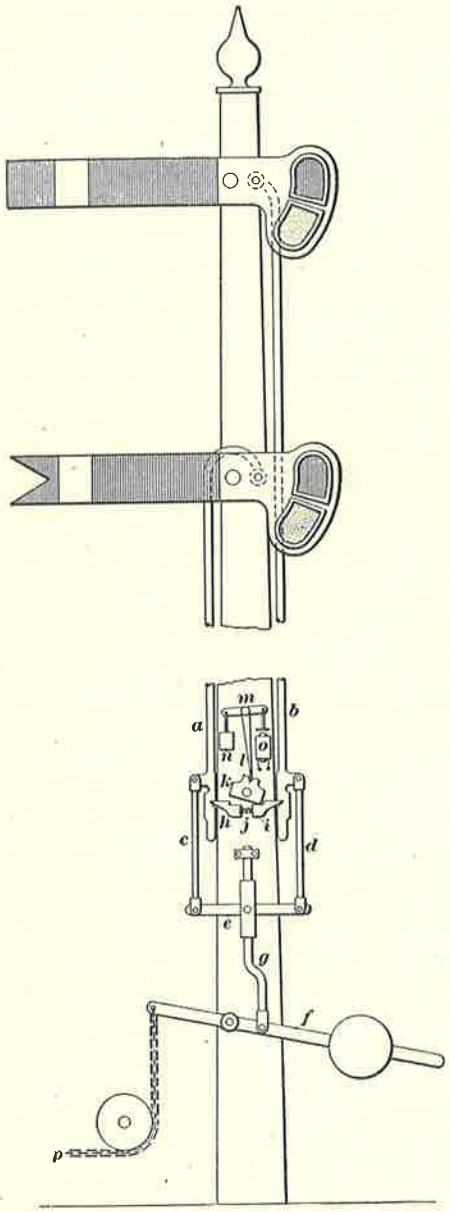

Fig. 18

31. Signal Selectors. It is sometimes desirable to operate separately one of two or more signals situated on the same post by means of one lever. This is accomplished by the use of a signal selector, which selects which one of the signals shall be operated by the lever. The selector is usually connected up in such a way that the signal selected depends on the condition of the track ahead. There are several types of selectors in use on different systems. The arrangement of one selector suitable for two signals is shown in Fig. 18. The two vertical signal rods *a* and *b* are coupled by means of the bars *c*, *d* to the cross-bar *e*, which is connected to the balance-weight lever *f* by the rod *g*. The lower parts of the rods *a*, *b* are furnished with notches, into which fit lock-bars *h*, *i*. The lower surface of each notch, and the lower surface of each lock-bar are bevelled, so that when the rods *a*, *b* are pushed upwards the

lock-bars tend to slide out of the notches against the action of the spring *j*. This tendency is controlled by the rocker *k*, which is turned from one side to the other by the pointer *l*, pivoted at *m*, and actuated either by the weight *n* or the electromagnet *o*.

32. Operation of Signal Selector.—The action of the mechanism of the signal selector shown in Fig. 18 is as follows: When one of the signals is to be put to the clear position, the lever in the signal box is pulled over, thus pulling on the chain *p* and raising the balance-weight lever *f* and the rod *g*. The upward motion of rod *g* is transmitted through the rods *e*, *c*, and *d* to the rods *a* and *b*, which both tend to rise. In the position shown, the electromagnet *o* is not energized, and the rocker *k* is tilted to the right by the action of the weight *n* and the pointer *l*. Lock-bar *i* is thus prevented from sliding out of the notch, and the rod *b* remains locked and cannot rise. Lock-bar *h*, however, slides out of the notch in rod *a*, which therefore rises, putting the lower signal to the clear position. Had the electromagnet *o* been energized, the rocker *k* would have been tilted to the left, and rod *a* would have been locked and rod *b* free. The upper signal would then have been lowered. The circuit of the electromagnet is controlled by the condition of the track ahead of the signals.

SYKES LOCK-AND-BLOCK SIGNALLING SYSTEM

33. Sykes Block Instrument.—One of the best-known and most-used lock-and-block signal systems in Great Britain is the Sykes system. The details of working and construction of instruments differ somewhat on different railways, but the main principle of operation is the same. The block instrument used is of the three-wire type, the up and down lines and bell having separate wires; the external appearance of the instrument is shown in Fig. 19. The instrument is provided at the top with a miniature semaphore *a* controlled from the station in advance. The dial *b* has two rectangular openings in its face, within the upper of which the words *free* or *locked* are displayed by the mechanism to show whether the signal connected with the

instrument is free to be operated or is locked. The lower opening either displays the words *train on* or shows a blank. The plunger *c* is used by the signalman when he wishes to accept a train from the preceding section, and the switch hook *d* is used to block the line during shunting operations. The block instrument is connected with the signal lever by the three rods *e*, *f*, and *g*. Of these, *e* is the signal-locking rod, *f* is the rod actuating the *train on* indication and locking the plunger when necessary, and *g* is the switching rod, which makes alterations in the electrical connections. When not in use, each instrument normally indicates *locked*, and has its miniature arm *a* at clear.

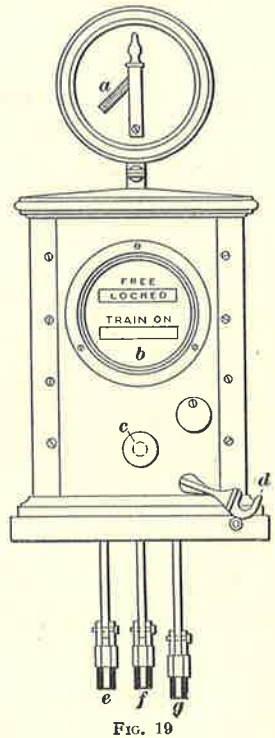

FIG. 19

34. Unlocking Magnet.—The electrical unlocking of the signals is effected by sending a current in a definite direction through the unlocking coils *a*, Fig. 20, which are fixed on soft-iron cores *b*, which form prolongations of the poles of the powerful permanent horseshoe magnet *c* in the block instrument. When the signal is locked, the magnet *c* holds an armature to its pole pieces against the action of a spring. To unlock the signal, a current is sent through the locking coils *a* in such direction as to neutralize the attraction of the permanent magnet, which then allows the

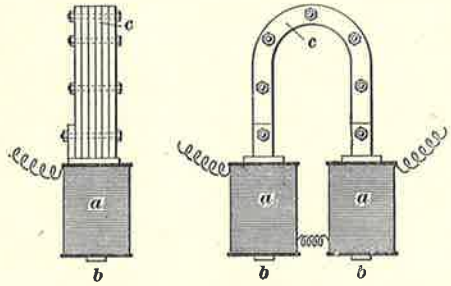

FIG. 20

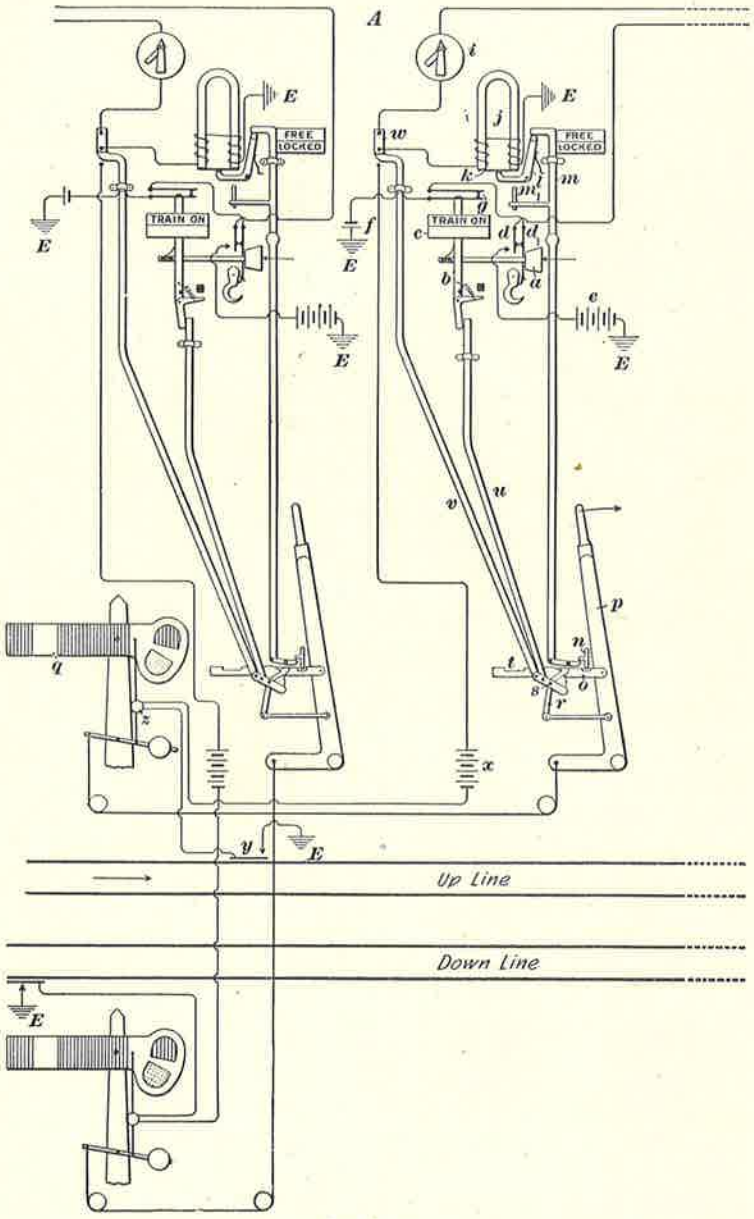

FIG. 21 (*a*)

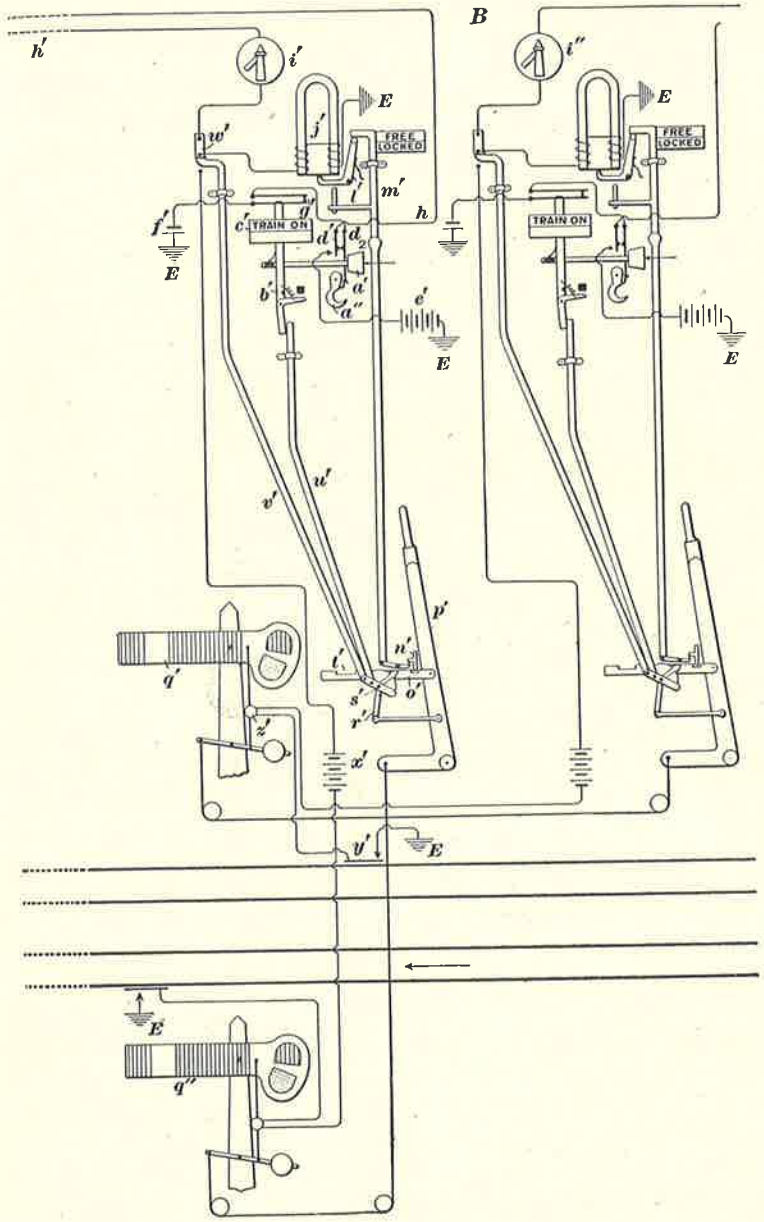

FIG. 21 (*b*)

armature to be pulled away by the spring, thus actuating the unlocking mechanism.

35. Operation of Sykes Signal System.—The operation of the Sykes lock-and-block signal system will be explained by reference to Fig. 21 (*a*) and (*b*), which shows the arrangement of the block instruments for a section of double track between *A* and *B*. The bell circuit, which is independent of the circuits of the block instruments, is omitted from the diagram in order to avoid complication.

If a train is at *A* and is to be sent on the *up line* to *B*, the signalman at *A* will first call up the signalman at *B* by means of the bell and give the signal asking if a train can be received at *B*. If the line is clear at *B*, the signalman will give the acceptance signal on the bell to the signalman at *A*, and will then push the plunger *a'* on the block instrument at *B* in the direction shown by the arrow. The plunger when pushed in is automatically locked, and the rod *b'* carrying the target *c'* is allowed to drop so that the words *train on* are displayed at the lower opening in the face of the instrument. The contact spring *d'* is joined by the movement of the plunger to the positive terminal of the battery *e'* and connection with the negative terminal of battery *f'* is broken at *g'*. The current from battery *e'* flows through the line wire *h* and causes the miniature semaphore *i* at signal box *A* to rise; current also flows through the coils of the permanent magnet *j*, thus demagnetizing the poles and releasing the armature *k*. The bell-crank lever *l*, which is attached to the armature, is moved to the left by a spring and the rod *m* is allowed to drop, thus displaying the word *free* in the upper opening of the instrument and raising the locking bolt *n* clear of the rod *o*.

36. The signalman at box *A*, Fig. 21 (*a*), can now move the lever *p* in the direction indicated by the arrow, thus lowering the starting signal *q*, which controls the up line between signal boxes *A* and *B*. On pulling the signal lever *p* to the clear position, the locking lever *r* is moved about its centre *s* and raises the rod *m* to the locked position, where it is held, because the armature *k* of the permanent magnet *j* is lifted into contact with the poles of the

magnet by a projection m_1 on rod *m*, thus moving the bell-crank lever *l* to the right and locking the rod *m*. The bolt *n* locks the signal lever *p* in the clear position by dropping into the slot *t*, which is made so wide that, when necessary for shunting, the lever *p* may be pushed back sufficiently far to set the signal *q* to danger without unlocking the block instrument for the acceptance of another train. The lever *r*, in moving in a counter-clockwise direction about the pivot *s*, draws rod *u* down, so that it will engage with a catch on rod *b* and raise the rod and the lower target *c* when the lever *p* is again placed in the position shown. The rod *v* is also drawn down when the signal lever *p* is moved to the clear position, and this causes the contact *w* to connect the terminal of battery *x* with the coils of the locking magnet *j*. When the train enters the block, it operates a rail contact *y* and connects the negative terminal of battery *x* to earth. Current flows from the battery *x* through the coils of the locking magnet *j*–earth *E*–rail contact *y*–signal reverser *z*–negative terminal of battery. This current causes the magnet *j* to release its armature *k*, which is forced downwards by the action of the spring on the bell-crank lever *l*, and the locking bolt *n* is raised by the falling of rod *m*. The word *free* is shown in the upper opening in the face of the instrument. The signal arm *q* moves to the danger position because of the action of the signal reverser *z*. The signalman at box *A* can now return the signal lever *p* to the danger position, where it is locked as shown in the diagram.

37. The signalman at box *B*, Fig. 21 (*b*), will call up the next signal box in advance and secure permission to admit the train to the block ahead of box *B*. When the plunger in the advance box is pressed, the miniature semaphore *i''* at box *B* moves to a horizontal position, and the block instrument to which it is attached unlocks the lever controlling the starting signal *q'*, thus allowing the signalman at *B* to move the signal *q'* to the clear position. If at any time the signalman at *B* wishes to perform shunting operations which involve blocking or fouling the up line in any way, he should first turn the switch arm *a''*, to the left, so that the insulated projection beyond the pivot will separate the springs *d'* and d_2 and interrupt the current from battery *f'*

to the line *h*, thus allowing the miniature semaphore *i* at box *A*, Fig. 21 (*a*), to go to the danger position. The hook at the end of the switch arm *a''* fits over the end of the plunger *a'*, which cannot again be used until the switch arm *a''* has been placed again in its normal position.

38. During the time that a train is running from *A* to *B*, Fig. 21 (*a*) and (*b*), on the up line a train may arrive at *B* to be sent on to *A* on the down line. The signalman at *B*, by means of the bell signal, asks if the train can be received at *A*, and if the down line is clear the signalman at *A* will depress plunger *a* of the block instrument, thus causing current to flow from battery *e* over the line *h'* to operate the miniature semaphore *i'* and cause the unlocking magnet *j'* to release the armature and unlock the lever *p'*, which controls the starting signal *q''*. The train is sent on from *A* in the same manner as described for a train on the up line at box *B*. Any signal referring to the down line may be given regardless of the positions of the pointers which refer to the up line, the two parts of each instrument working independently.

39. Permissive Working of Sykes System. — At very busy points it is sometimes desirable to have a permissive system of signalling, so that more than one train may be allowed in a block at a time. In the Sykes lock-and-block signalling system two trains may be fully protected in one block by means of a permissive arrangement, consisting of an *advance starting signal* placed near the middle of the block between two signal boxes and controlled from the box ahead. The first train is allowed to enter the block in the usual way and the starting signal is put to danger behind it. The starting signal and the advance signal are interlocked so that the starting signal cannot be put to the clear position to admit the second train until the first train has passed a rail contact ahead of the advance signal and set it to danger. After the first train has passed out of the advance section of the block, the advance starting signal can be placed at clear to admit the second train. The operation of the permissive system is thus essentially the same as though an additional signal box were situated at the place where the advance starting signal is.

TYER LOCK-AND-BLOCK SIGNALLING SYSTEM

40. Construction of Tyer Lock-and-Block Instrument.—The lock-and-block instrument used with the Tyer lock-and-block signalling system is provided with two miniature semaphores, one for the up line and one for the down line. The lower semaphore in each instrument serves as an indicator of the signal sent to the next station. The commutator consists simply of a two-piece metal ring, the smaller segment *a*, Fig. 22 (*a*), forming an arc of about 60°. The two parts *a* and *b* are carefully insulated from each other, and are placed so that the spring *1* and spring *2* are joined to each other and spring *3* is connected to spring *4* when the commutator is in the position to display the notice *train out of section* on sector *D* or *train on line*, the latter notice being on a stationary vane behind sector *D*. If the sector *F* bearing the words *line clear* is in view, the commutator segment *a* will connect springs *1* and *3* and segment *b* will connect springs *2* and *4*. The effect of this change is to reverse the connections to the battery *c*.

41. The sector *D*, Fig. 22 (*a*), bearing the words *train out of section* is loose on the commutator shaft, and the sector *F* indicating *line clear* is fixed to the shaft and turns with it. If the commutator handle is turned in a counter-clockwise direction the sector *F* comes against the sector *D* and moves it to the left, so that sector *F* is in view. After the line-clear signal has been given the handle may be turned in a clockwise direction, thus carrying sector *F* to the right. Sector *D* is held to the left by the lever *k* being caught by the hook on the armature of unlocking magnet *l*. When the words *train on line* are in view the *line-clear* indication cannot be given, as the lever *d* drops down so as to catch the edge of the sector *F*. The indication *train out of section* must therefore be given, so that sector *D* raises lever *d* each time before *line clear* can be obtained at the commutator. Signal replacers and track contacts are used in connection with the Tyer lock-and-block signal system. The signal levers are locked when in the danger position only, though it is possible to arrange the apparatus for double locking, if desired.

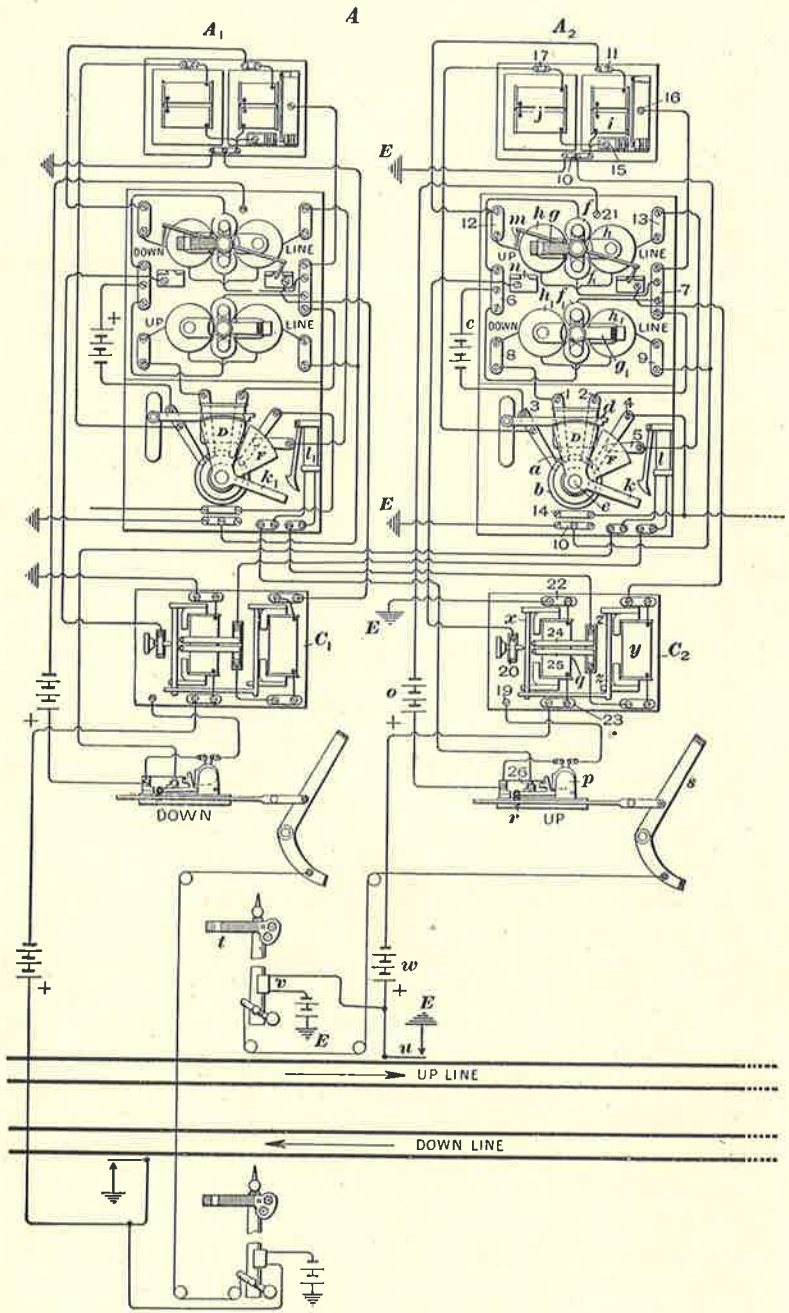

FIG. 22 (*a*)

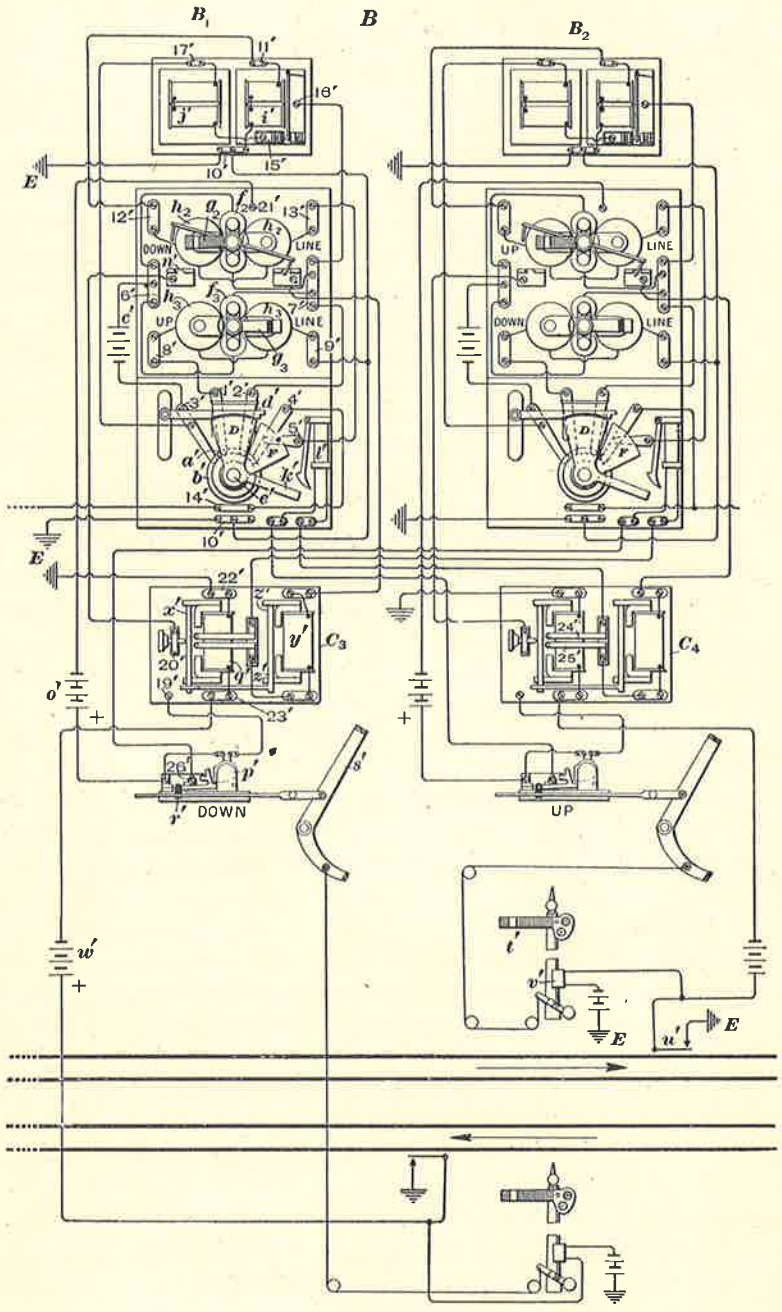

FIG. 22 (*b*)

42. Operation of Tyer Lock-and-Block System. — The connections of the instruments at adjacent signal boxes A, B for the Tyer lock-and-block signalling system are shown in Fig. 22 (a) and (b). The two instruments A_2 and B_1 will be in use when it is desired to send a train from A to B on the up line or from B to A on the down line. In order to explain the working of the apparatus, it will be assumed that a train is to be sent from A to B. The signalman at A will depress the plunger e of the instrument A_2, thus causing the commutator segments a and b to connect the springs *1*, *2* and *3*, *4*, respectively. At the same time, contact between spring *4* and stud *5* is broken. A momentary current flows from the positive terminal of battery c–terminal *6*–exciting fields f, f_1–terminal *7*–spring *2*–segment a–spring *1*–terminal *8*–fields h_1–terminal *9*–terminal *10*–earth E to receiving instrument B_1–terminals *10′*–windings of relay i'–terminal *11′*–terminal *12′*–fields h_2–terminal *13′*–stud *5′*–spring *4′*–terminal *14′*–line to instrument A_2–spring *4*–segment b–spring *3*–negative terminal of battery c. The armature of relay i', of instrument B_1, is attracted against the stud *15′*, thus giving a circuit from the positive terminal of the battery c'–terminal *6′*–exciting coils f_2, f_3–terminal *7′*–terminal *16′*–armature of relay i'–stud *15′*–windings j' of ringer–terminal *17′*–spring *3′*–negative terminal of battery c'. The semaphores g_1 of instrument A_2 and g_2 of instrument B_1 will remain up, as the current tends to hold the armatures in the original positions; the bell of instrument B_1 will ring.

43. The signalman at B, Fig. 22 (b), will, if the line is clear, turn the handle of the commutator of instrument B_1 to the left, thus bringing the notice *line clear* on sector F into view and raising the lever k' above the hook on the armature of the unlocking coil l'. When the plunger e' is depressed, the positive terminal of the battery c' will be connected to the line through springs *2′* and *4′* and commutator segment b'. The reversal of current in the line circuit will cause the semaphores g_3 of instrument B_1 and g of instrument A_2 to drop. The lever k' of the sector D is held up by the hook on the armature of the unlocking coil l'. The unlocking coil l' is not excited, as the circuit through it is open at the springs *24′* and *25′* of the lower relay C_4.

44. When the upper semaphore g of instrument A_2 at station A, Fig. 22 (a), drops, the contact m is brought into the mercury cup n. A circuit is thus formed from the positive terminal of battery o–unlocking magnet p of the signal lever s–stud *19*–on relay C_2–armature x–contact stud *20*–mercury cup n–contact m–terminal *21*–negative terminal of battery o. The armature of the signal unlocking magnet p is attracted, thus raising the lock r so that the lever s can be moved and the semaphore t set to indicate a clear line. As soon as the signalman at A has set the starting semaphore t to clear, he signals on the bell to indicate at station B, Fig. 22 (b), that a train is entering the section. On receipt of this information the signalman at B will turn the commutator of instrument B_1 to the right, thus moving the sector F to one side, so that the words *train on line* are brought into view. The sector D is held to the left by the lever k' and the hook on the armature of magnet l'. When the signalman at B depresses the plunger e' to send the *train on line* signal to the signalman at A, the direction of current is such that the semaphores g_3 and g are raised to the danger position.

45. As soon as the train has entered the section at A, Fig. 22 (a), it passes over a rail contact u and causes the signal replacer v to set the starting signal t to danger. There is also a circuit formed from the positive terminal of battery w–rail contact u–earth E to terminal *22* of relay C_2–winding q–terminal *23* and to negative terminal of battery w. The magnetism set up by the current in coil q will attract the armature x and thus join springs *24* and *25* of the relay. A circuit is thus completed from the positive terminal of battery o–contact *26* on locking magnet for up signal lever s–through the unlock magnet l_1 of instrument A_1–spring *24* of relay C_2–armature x–spring *25*–magnet coil y–right-hand mercury cup–contact of semaphore g–terminal *21*–negative terminal of battery o. The unlock magnet will attract its armature and the weight of the lever k_1 will cause the *train out of section* sector D to move into view before the window in the front of the instrument. Magnet y will attract armature z and this will release armature x, which will take up its original position and break contact with springs *24* and *25*.

OPERATION OF SINGLE LINES

46. Original Method.—The safe working of single lines, over which trains must travel in both directions, is a much more difficult problem than the operation of double lines. In the early days of railway working, a pilotman was allotted to each section of single line. This pilotman accompanied all trains over the section, and if there were two trains waiting to proceed in the same direction, he dispatched the first and followed with the second, or with the last, if there were more than two. The pilotman usually issued tickets to the advance trains as authority to proceed without him. The place of the pilotman was afterwards taken by a wooden train staff. There was one train staff to each section, without which no train was allowed to enter a section. To provide for cases where more trains than one were waiting to enter a section in the same direction, tickets were provided, which were placed in a box which could be unlocked only by the train staff itself. The train staffs were eventually made of metal, and so constructed that they could be used to unlock the ticket box, but could not be removed until the lid of the ticket box was closed. Even with this method of working, there were errors and delays which made the method both unsafe and wasteful of time.

47. Use of Staff and Tablet Instruments.—In order to overcome the difficulties of the early train-staff systems, instruments were devised which issued train staffs or tablets under the control of lock-and-block systems of telegraphing. The instruments are so arranged that a staff or tablet cannot be withdrawn at one end of the section without the concurrence of the signalman at the other end of the section, and that when a staff or tablet is issued from end A of a section it is impossible to issue one from end B until the tablet issued at A is placed in the machine at B. The staff- or tablet-issuing machines can be electrically interlocked with the signals in such a way that the starting signal at one end of a section cannot be lowered until a staff or tablet has been obtained, thus making it impossible to show a clear signal if there is a train on the line.

POWER OPERATION OF POINTS AND SIGNALS

ELECTRIC AND ELECTRO-PNEUMATIC SYSTEMS

48. Advantage of Power Operation.—In early systems of signalling, and in many of the present ones, the work of moving points and signals is done by the signalman by means of levers connected through systems of rods, wires, and bell-cranks to the points or signals to be operated. Where the points or signals are situated at some distance from the signal cabin, the physical exertion required to operate them is often very great. The effect of this is to prevent the signalman from giving his whole attention to the train movements. The system of rods and wires necessary to work the points and signals of a large junction or terminus are often exceedingly complicated, and necessitate very large and unwieldy locking frames to contain all the levers. In order to obviate these difficulties, many railway companies are replacing the manually operated points and signals by those operated by power.

The points and signals may either be worked by compressed air or by small electric motors or solenoids. Whichever system is employed, the control is effected electrically by contacts in the signal box. As the levers for the points and signals merely operate electrical switches, they need only be large enough to give mechanical strength and to permit of being effectively locked; these levers can be moved with the utmost ease. The locking frames are greatly reduced in size and the interlocking very much simplified. For automatic signalling, power operation of the points and signals is, of course, essential.

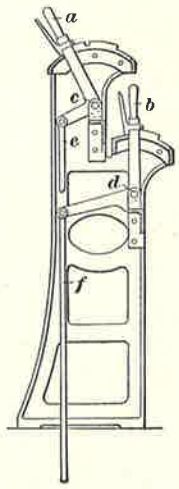

FIG. 23

49. Operation of Controlling Switches.—The arrangement of two of the point levers for an electrically operated system is shown in Fig. 23. The levers *a* and *b* are at a height of about 4 feet and 3 feet, respectively, above the floor of the cabin.

They are pivoted in a light framework at *c* and *d*, and operate the switches for making the requisite connections to points and signals by means of the rods *e* and *f*. The type of switch used with the point levers shown in Fig. 23 is illustrated in Fig. 24.

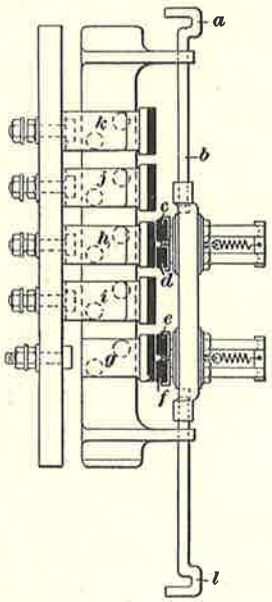

FIG. 24

An extension of the rod from the point lever is attached to the hook *a* on the rod *b*. The rod *b* carries two sets of carbon brushes, *c*, *d* and *e*, *f*, which press normally on the contact-blocks *g*, *h*.

50. Use of Check-Lock.—In a power system of signalling it is necessary to arrange matters so that a signalman shall not be able to complete the movement of a point lever, thus unlocking the signals in connection with the points, until the points themselves have moved to their proper position, and been bolted there. This is accomplished by means of a check-lock, which only allows a point lever to be moved half-way over at first. This allows the carbon brushes *c*, *d*, Fig. 24, to connect contact-blocks *j*, *k*, and brushes *e*, *f* to connect blocks *h*, *i*, thus sending power to operate the points. As soon as the points are bolted in place, a contact is made which releases the check-lock attached to the hook *l* and enables the movement of the point lever to be completed. The full movement of the lever unlocks the signals which have reference to the points.

51. Construction of Check-Lock.—The construction of the check-lock is shown in Fig. 25. The eye *a* on the bar *b* engages with a hook on the rod from a point lever, and the bar *b* is provided with two lugs *c* and *d*. Two pawls *e* and *f*, pivoted at *g* and *h*, respectively, are arranged so that one end of each is opposite to one of the electromagnets *i* and *j*. When the point lever is half-way over, lug *d* engages with pawl *f*, preventing further movement of the lever. When the points are finally bolted in

position, electromagnet *j* is energized and attracts pawl *f*, thus freeing lug *d* and bar *b* and allowing the movement of the lever to be completed. Similarly, when the points are put back, the pawl *e* engages with the lug *c* and prevents complete movement of the point lever until the electromagnet *i* is energized. In addition to the point check-lock, the point levers are interlocked with the block instruments in the same way as with the ordinary manual system.

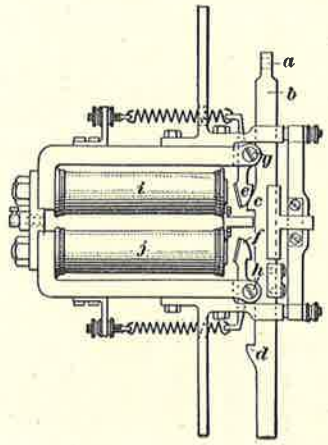

FIG. 25

52. Electrically Operated Point Movement.—The layout of an electrically operated point movement is shown in Fig. 26, view (*a*) being a plan, view (*b*) a side, and view (*c*) an end elevation. The enclosed motor *a* is mounted on the sole plate *b* bolted to the sleepers. The motor is connected by the universal joint *c*, which allows for the shafts being out of line, to the small friction clutch *d* and the worm *e* engaging with the worm-wheel *f*. Attached to the worm-wheel is a crankpin *g*, which moves inside the hollow cam-lever *h*, pivoted to the base at *i*. The end of the cam-lever is connected to the rod *j*, which operates the points through the rod *k*. The pin *g* on the worm-wheel *f* has also attached to it the rod *l*, which, through crank *m* and rod *n*, rotates the spindle *o* and raises the locking bar *p* by means of the rod *q*. This bar prevents the movement of the points during the passage of a train, since, in order to reverse the points, the bar *p* must be raised above the level of the rails.

53. The movement of the bar *p*, Fig. 26, is communicated to a second spindle *r* by the rod *s* and produces a thrust on the rod *t*, which thrust is transmitted to the sway beam *u* pivoted to the end of the rod. The sway beam carries at its ends two plungers or bolts *v*, *w*; when the points are home in one or the other of their two positions, holes in the stretcher bar *x*, which

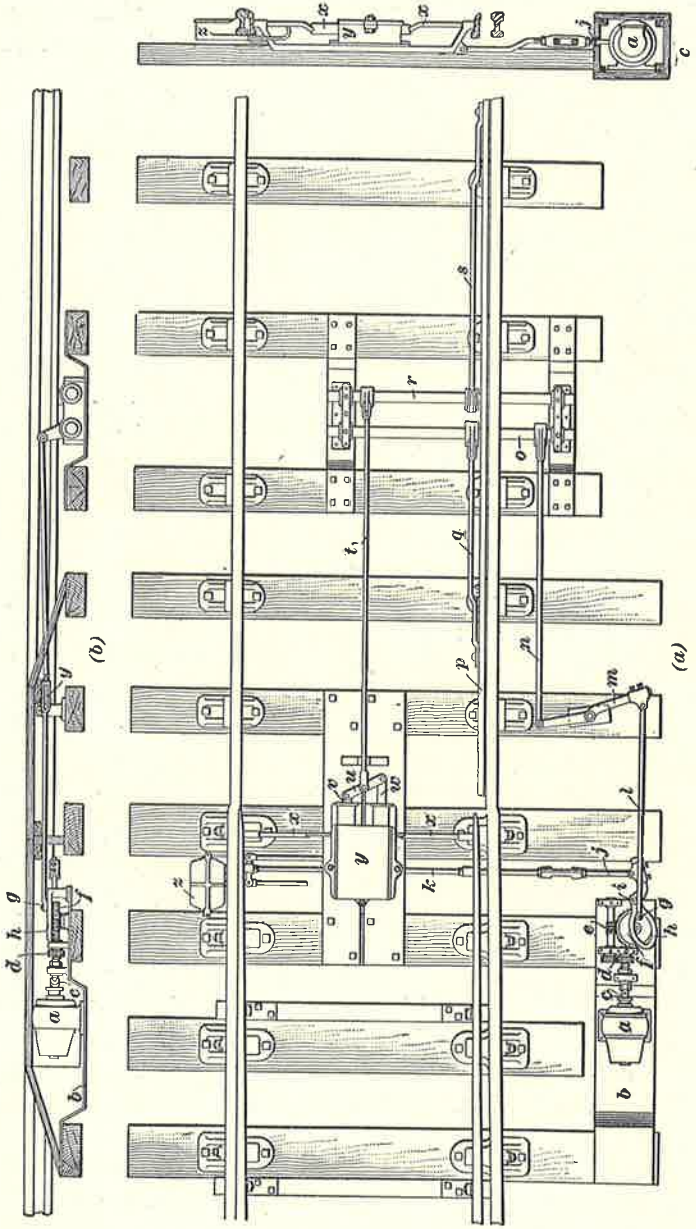

FIG. 26

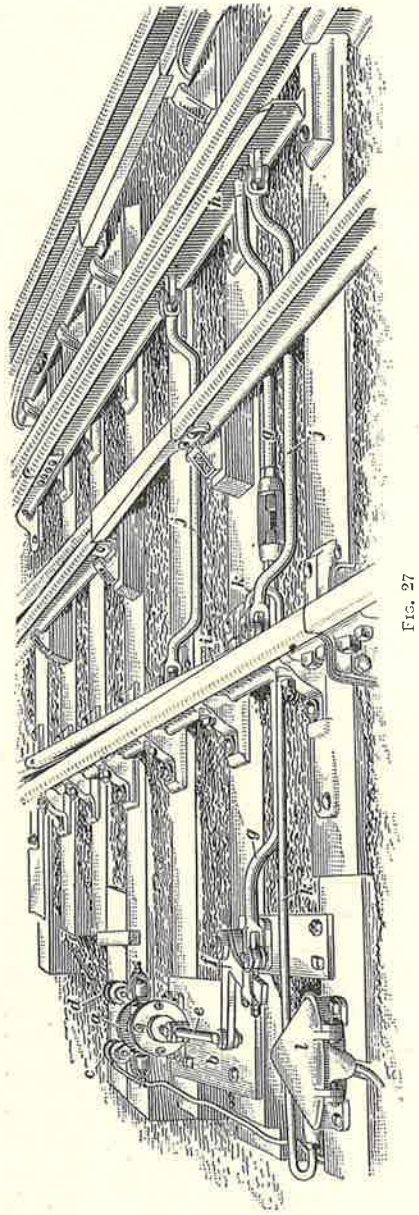

FIG. 27

connects the tongues of the points, come opposite to either plunger *v* or plunger *w*. Thus, in one position, plunger *v* passes through a hole in bar *x* and locks the points, and in the other position, plunger *w* passes through a hole in the bar and locks the points. Situated in the box *y* are contact springs actuated by the movement of the points, which break the motor circuit and reverse the connections to the motor armature when the movement is completed. The box *z* contains contacts connected with the signals in such a way as to prevent their operation unless the points are correctly set. The time taken to reverse the points is between $1\frac{1}{2}$ and 2 seconds, and the power required is about 6 amperes at 110 volts.

54. Electro-Pneumatic Point Movement.—In the electro-pneumatic system of operating points and signals, a main, carrying air at a pressure of 65 to 70 pounds per square inch,

is carried the whole length of the track to be signalled. Air from this main is admitted to one side or the other of a piston working in an air cylinder. The piston is thus forced in one or the other direction and actuates the points through a system of levers. The admission of air to the cylinders is governed by pin valves, which are controlled by electromagnets. A trailing point layout, where trains converge from two branches on to a single line, is shown in Fig. 27. The main air cylinder *a* is mounted on an iron base plate *b* secured to the sleepers. The electrically operated pin valves for controlling the admission and release of air are placed in the cases *c* and *d*. The motion of the piston is communicated through the rod *e*, crank *f*, and rod *g* to the point tongue *h*. The second point tongue *i* is operated from the first by the rods *j*. Attached to the second point tongue *i* is a rod *k*, which passes into the box *l* and actuates the switches for releasing the various locks on signals, point levers, etc., and for indicating that the points have properly closed.

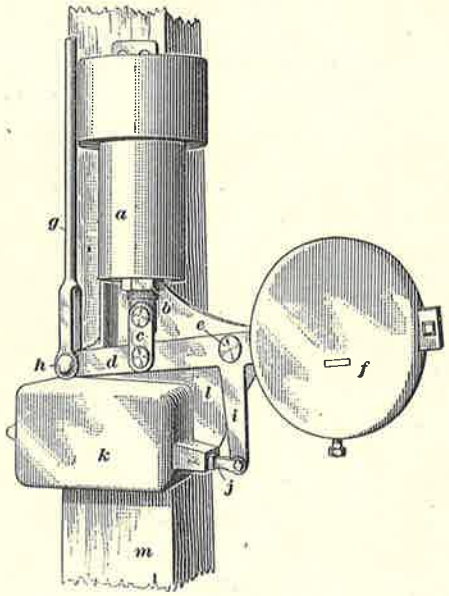

FIG. 28

55. Electrically Operated Signals.—Signals may be operated electrically by either motors or solenoids, and both methods are quite satisfactory. The way in which a signal is operated by means of a solenoid is shown in Fig. 28. The winding of the solenoid is contained in a cast-iron case *a*, and the plunger *b* is connected by the link *c* to the lever *d*, which is pivoted at *e* and provided with a counterweight *f*. The signal rod *g* is

attached to the lever *d* at a point *h* beyond the link *c*. The signal arm is balanced so that it returns to danger when the solenoid is not energized. The arm *i* of the lever *d* actuates the rod *j*, which passes into the switchbox *k*. The solenoid requires a current of about 15 amperes at a pressure of 100 volts for a fraction of a second to pull the signal arm to the off-position, but to hold the arm at off only about 2 amperes is required. On this account, as soon as the signal is off, a resistance is switched into circuit with the solenoid winding by a carbon contact switch placed in the box *k*, and actuated by the rod *j*. The whole movement is mounted on a cast-iron base *l* and attached to the signal post *m*.

56. Electro-Pneumatic Signal Movement.—A sectional view of the air cylinder, control valve, and magnet of an electro-pneumatic signal movement is shown in Fig. 29. The compressed air from the main enters at *a* and is controlled by the valve *b*, carried on the end of the rod *c*, which is attached to the armature *d* of the electromagnet *e*. The valve *b* has two seatings. When the signal is in the normal *on-* or *danger* position, the electromagnet *e* is not energized, and the valve *b* is held up against the lower seating by a spiral spring, the upper part of the valve being open. This shuts off the compressed air and connects the upper part of the air cylinder *f* to the exhaust port *g* through the passage *h* and upper part of valve *b*. When the signalman pulls over the control lever the electromagnet *e* is energized and attracts its armature *d*, thus forcing the valve *b* down away from its lower seating and closing the upper seating. The compressed air then passes through the lower part of valve *b* and passage *h* to the upper part of cylinder *f*, forcing down the piston *i* and piston rod *j*, which is connected to the

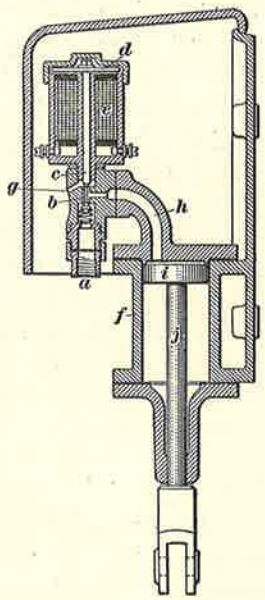

FIG. 29

signal rod through a lever. The signal is thus forced to the off- or clear position. When the magnet is again de-energized, the compressed air is again cut off at the lower part of valve *b*, the upper part of cylinder *e* is connected to the exhaust port *g*, and the signal returns to the on-position by gravity.

AUTOMATIC SIGNALLING SYSTEMS

ARRANGEMENT OF BLOCKS AND AUTOMATIC SIGNALS

57. Necessity for Automatic Signalling.—As traffic on the railways increased with but slight increase of track length, it became necessary to run the trains closer together, for which purpose the length of the block sections had to be reduced. In many cases the cost of providing a signal cabin for each block would be prohibitive; this and other reasons led to the invention of systems which would work automatically and dispense with the services of signalmen, such systems being known as **automatic block-signal systems.**

The operation of the signals of the **automatic block-signal system** is entirely controlled by the trains using the track to which the system is applied. A proceed signal is displayed to an approaching train, at the entrance to a block, provided that no other train is in the block and that it contains no open points or broken rail. The signal moves to the stop position as soon as the first pair of wheels of a train passes the entrance of the block, and the signal remains at this position until the last pair of wheels of the train has passed out of the block at the distant end.

Automatic signals are so arranged that they are held normally at clear. This is the case because the duty of an automatic signal is to indicate whether the section ahead of it is occupied or not. It should thus only stand at danger when there is a train in the section ahead. In case of any failure of the apparatus, however, automatic signals are arranged to return to the danger position by gravity.

58. Length of Block Sections.—In order to secure the safe maximum capacity for train movements over a given piece of track, it is necessary to know the maximum distance required for stopping the fastest train on the road. Air-brake tests will determine this distance, and for maximum train capacity, the length of the block should be equal to this value, but should not be less.

Since it is more difficult to stop on a descending grade and less difficult to stop on an ascending grade, the blocks should be lengthened on descending grades and shortened on ascending grades. As large terminals are approached, the blocks should be shortened on account of the limited speed of trains and the congestion of traffic at such places.

59. General Requirements of Signal Control.—Having fixed the positions, the control of the signals should be such as not only to warn the driver of the train when he reaches a block that is occupied, but also to warn him in time to permit him to stop the train before reaching the entrance of the occupied block. With this arrangement and control of signals, it would be possible to start two trains from one end of the line, space them two blocks apart, run them the length of the line at the same speed, and have them still two blocks apart when the first train reached the end of the line. The second train would receive clear signals all the way; or, if the first train should stop at any point, the second would receive due warning and have plenty of space in which to stop before reaching the block occupied by the first train.

60. Arrangement of Blocks.—In Fig. 30 is shown an arrangement of an automatic block system using semaphore home and

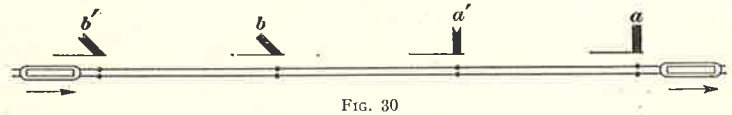

FIG. 30

distant signals mounted on separate posts. The ends of the home-signal arms are square, while the ends of the distant-signal arms are notched. The home signal *a* is shown in the

stop position, with a train just past it in the block. The distant signal for *a* is shown at *a'*. This signal is in the caution position, indicating to an approaching train, *expect to find the next home signal in the stop position.* Home signal *b* and distant signal *b'* are in the proceed position, since the train has just moved out of the block *a b*. Under this arrangement trains can be run at full speed, provided they are spaced a distance equal to one block, *a b*, plus the distance, *b b'*, between a home signal and its distant signal.

61. The indications and meanings of the signals shown in Fig. 31 are identical with those described in the preceding article. This arrangement is developed by reducing the length of blocks *a b*, *b c*, etc., until the home and distant signals *a'* and *b*, *b'* and *c*, etc., are so close together that it is best to mount them on the

FIG. 31

same post. Distant signal *b'* has just gone to clear, since the train has passed out of block *a b*. With this arrangement, trains running at full speed would be spaced two blocks apart, although the actual distance might be the same or shorter than that shown in Fig. 30.

62. Overlap.—In cases where an exceedingly frequent service of trains is maintained, as on underground electric railways, and the blocks are correspondingly short, distant signals are dispensed with, and the entrance of a train to each block is controlled by a starting signal. Each signal is governed by the condition of the section immediately in advance of it, and this section commences a certain distance in advance of the signal and extends to a similar distance beyond the next stop-signal. The distance by which the section extends beyond the signal is known as the **overlap.** The purpose of the overlap is to guard against a collision which might be caused by the driver passing a signal at danger, by allowing an additional space in which to bring the train to a stop before it enters the next section.

63. Automatic Train Stop. — As an additional safeguard against trains running past stop-signals, an **automatic train stop** is often used. This device is illustrated in Fig. 32, and consists of an arm *a*, standing beside the track rail *b*, outside the track. This arm is mounted on the spindle *c*, which is connected by the crank *d* and rod *e* with an air cylinder *f*. The admission of air to this cylinder is controlled by an electrically operated pin valve contained in the case *g*. When the adjacent signal is in

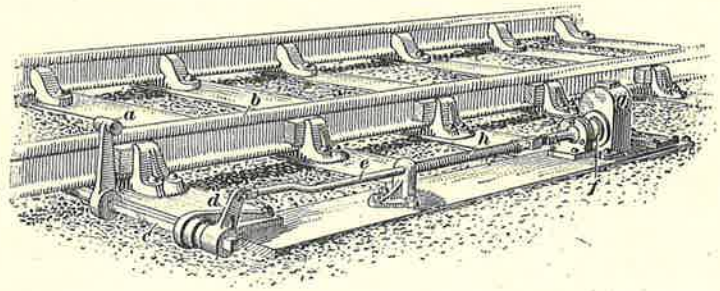

FIG. 32

the stop position, the spring *h* on the rod *e* forces the rod to the right, and the stop is raised. When the signal is lowered, air is admitted to the cylinder *f*, which forces rod *e* to the left and lowers the arm *a*. If a train passes over the arm *a* when it is raised, as shown in the illustration, the arm strikes the handle of a special valve which applies the air brakes and stops the train.

TRACK CIRCUITS

64. Principle of Operation.—It is clear that if the track rails themselves are used as the signal circuit, by connecting a battery across them at one end of a section, and a relay at the other, the relay will be energized as long as there is no train in the section, and will complete the circuit holding the signal in the clear position. When a train enters the section, the track rails will be short-circuited through the wheels and axles of the train, and but little current will flow through the relay, which will therefore drop its armature, and allow the signal at the entrance

to the block to return to danger. The track-circuit principle is used not only in connection with automatic signals, but also for locking purposes where the signals are controlled by a signalman. It is often used to replace fouling bars.

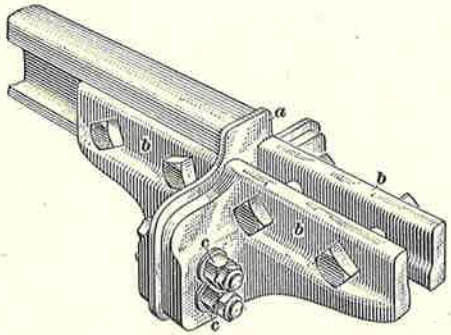

FIG. 33

65. Insulated Rail Joints.—The installation of a section of track circuit necessitates the replacement of the iron fish-plate joints at each end of the section with an insulated joint, and the bonding together of the intermediate rails by running bonds of wire round each joint to reduce the resistance. A type of insulated joint for ordinary rails is shown in Fig. 33, one rail being removed in order to show the plate of insulating material *a*, which is clamped between the special fish-plates *b*. The clamping bolts *c* are insulated from the fish-plates by means of fibre washers and bushes.

66. Arrangement of Track Circuit for Steam Railways.—On steam railways, where both rails can be used for carrying current

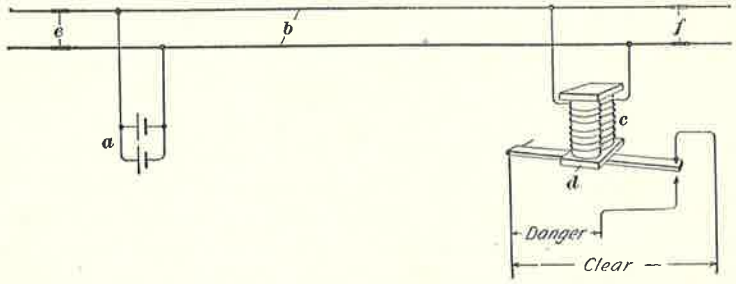

FIG. 34

for signal work, the track circuit takes the form shown in Fig. 34, in which the batteries *a* are connected across the rails *b* at one end of the insulated track section *e*, *f*, and the relay *c* is connected

across the rails at the other end. The relay has a pivoted armature *d* that carries contacts for controlling the signal, or auxiliary, circuits. The armature falls away from the magnet cores by gravity and requires that the magnets be energized in order to raise it. The track circuit is a closed circuit, and the relay is normally energized. The breaking of any wire in this circuit or the short-circuiting of the relay, caused by crossed wires or a train on the track circuit, in which event the wheels and axles cause the two rails to be connected together, will cause the relay armature to fall away from the cores, and break the circuit which supplies current to the apparatus holding the signal in the clear position.

WESTINGHOUSE TRACK-CIRCUIT SIGNALLING SYSTEM

67. Arrangement of Conductors and Track Sections.—When applying track circuits to an electric railway, great care has to be taken that the relays employed are not operated by leakage currents from the main conductors carrying the operating current for the trains. For this reason it is not possible to use the simple system shown in Fig. 34 for signalling on electric railways. A very successful system of track-circuit automatic signalling, which is unaffected by leakage currents, has been installed by the Westinghouse Company on several of the underground electric railways of London. In Fig. 35 is given a diagram of the connections of the system as installed on the Metropolitan District Railway. On this railway the track rails are not used as the return circuit for the current supplied to the trains, but the signalling system may be used where one of the track rails is made to carry the return current from the car motors. One track rail *a* is bonded up to form a continuous conductor, and this rail is connected to the positive pole of the direct-current generator *c*, which supplies current at a pressure of about 60 volts. The second track rail is divided up by insulated rail joints into sections b, b_1, b_2, b_3, etc. An insulated signal main *d* is connected to the negative pole of the generator *c* and runs the whole length of the line. Each of the blocks of the sectionalized track rail is connected to the negative signal main through a resistance *e*, *f*, *g*, respectively, as shown.

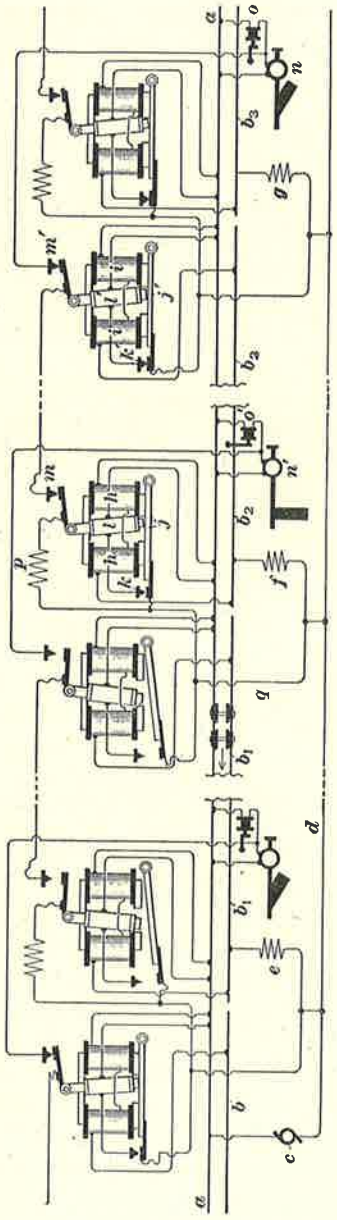

FIG. 35

68. Action of Relays. — In the Westinghouse track-signalling system two relays are employed for each section, one being connected across the track rails at each end of a section. It is necessary for the contacts of both these relays to be closed at the same time before the signal can go to the clear position. The two relays for section b_2, Fig. 35, have their main windings h, h and i, i, respectively, connected between the rail a and rail b_2 at opposite ends of the section. When there is no vehicle on the section, current circulates through the main windings h, h of the left-hand relay, causing the keeper j to rise and close the contact k. This connects the winding l of the relay armature, which is of high resistance, between the rail a and the signal main d. The relay armature is magnetized in such a direction that it is attracted by the right-hand pole piece of the relay, and closes contact m. In a similar way, the main windings i, i of the relay at the other end of the section are energized, and cause keeper j' to close contact k', thus exciting the armature l' and closing contact m'. The circuit through the signal magnet n is also closed.

69. When the contacts m and m', Fig. 35, of the relays connected to track section b_2 are closed, current can flow from the rail a through the valve-operating coils of signal n and train stop o in parallel, through contacts m' and m in series, and back to the signal main d by way of resistance p and wire q. Compressed air is admitted to the cylinders of the signal and train stop, and both are put in the clear position. When a car or train is in a block, as shown for section b_1, the main windings of the relays connected to the section are shunted by the wheels and axles, and the relays are de-energized, opening the signal and train-stop circuits in two places, and allowing the signal and stop to go to the danger positions, as shown at n' and o'.

70. Effects of Leakage Currents.—The relays at the opposite ends of a section are so connected up that they cannot be both energized in the normal direction when a train is in the block. The possible conditions due to currents from other sources than the generator c, Fig. 35, may therefore be summarized as follows: (*a*) Both relays shunted. Normal condition. Circuit broken in two places. (*b*) One relay shunted, the other energized normally. Circuit broken in one place. (*c*) One relay shunted, the other energized reversely. Circuit broken in two places. (*d*) Both relays energized, one normally and one reversely. Circuit broken in one place. Under all these conditions the circuit is broken at one place at least, and the signal and train stop for the section remain in their danger positions.

71. Length of Overlap.—It is shown in Fig. 35 that a section does not end until some little distance after the stop-signal for the next block has been passed; in other words, there is a considerable overlap. In the system under consideration, the average length of the blocks on the busiest part of the line is 900 feet, and on other parts varies between 900 and 4,000 feet. The length of the overlap is 400 feet, this allowing ample space for the train to be brought to rest by the train stop. In a test on a train consisting of seven cars, travelling at full speed on a down grade of 1 in 460, the train was brought to a standstill in 218 feet, or a little more than half its own length.